Oil and Gas in the Mid-Continent Fields

By

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PREFACE

This book is an attempt to put in concise form the essential information concerning the Mid-Continent oil and gas fields. The material has been derived from many sources. The various publications of the United State Geological Survey and those of State Surveys of Kansas, Oklahoma and Texas have been used extensively. In general, references have been made to publications where any important material has been taken from them, but it has been impossible to give credit for all the small items gathered from various sources or for those obtained as a result of the writer's associations with other geologists and oil-field workers.

Special sections have been prepared by S. E. Murphy, L. H. Pasewalk, F. W. Reeves, W. C. Bean, L. W. Kesler, F. L. Aurin and E. P. Hindes of the Empire Companies; by C. Max Bauer of Okmulgee, Okla., and by F. B. Plummer, Geologist for the Roxana Petroleum Company. These articles are given under the names of their respective authors.

In addition to those named above, the writer wishes to express his thanks to Everett Carpenter, A. W. McCoy, Geo. E. Burton, W. R. Berger and E. W. Scudder of the Geological Department of the Empire Gas & Fuel Company and to R. B. Lloyd, Chief of the Scouting Department of the same company, for their interest and assistance in the preparation of the book.

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L. C. SNIDER.

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CHAPTER I.

ELEMENTS OF GEOLOGY.

NATURE AND MODE OF FORMATION OF ROCKS.

Rocks are divided into three great classes—igneous, sedimentary, and metamorphic. The igneous rocks are those which were formed by the action of heat (*ignis*, Latin for fire). They have cooled into their present form from a liquid or molten condition. The igneous rocks are generally hard and crystalline and do not, as a rule, occur in layers or beds. There are very many types of igneous rocks of widely varying appearance and texture, but granite is probably the most common and best known variety.

It is the prevailing type of igneous rock in Oklahoma, where it occurs in the Arbuckle and Wichita mountains and in a small area in Mayes county. In Kansas granite is known only from well records in the central part of the state. Granite and related igneous rocks form the central part of the Llano-Burnett mountains in central Texas. There are large areas of igneous rocks in trans-Pecos Texas and small scattered bodies in south-central Texas.

Although very important in the study of geology as a whole, the igneous rocks occupy relatively very small areas in the states under consideration. They are also unimportant in connection with the study of oil and gas, for, with some minor exceptions, commercial deposits of these substances have not been found in igneous rocks. For these reasons, these rocks will receive no further notice.

The sedimentary rocks—as is indicated by their name—are those which were deposited as sediments in water. We know that ages ago all the territory now included in the Mid-continent fields was covered by the ocean for vast periods of time. Gravel, sand and soil were washed down by the rivers from the surrounding land and deposited as layers of sediment on the ocean bottom. These

sediments in many places were piled up to thicknesses of thousands of feet before the ocean was finally withdrawn and the area became land. Since the rocks of practically all of Oklahoma are sedimentary and since all the oil and gas occur in these rocks, an understanding of the method of their formation and their relations is important.

The sedimentary rocks consist of shales or mud rock, sandstone, limestone, chert or flint, and conglomerate or pudding stone, named in the order of abundance. The conglomerates, sandstones, and shales were formed by the gravel, sand, and mud respectively which were washed down from the surrounding land into the ancient ocean and settled to the bottom. The limestone was built up principally of the shells of sea animals. When the animals died these shells sank to the bottom and accumulated there. For the most part the shells were partially dissolved and were ground up by the wave action into a lime mud which preserved no trace of the shell structure. In many cases, however, the shells were preserved entire and some of the limestones of these states are largely made up of well-preserved fossil shells. Fossil shells are also found in shale, and the shells or their impressions in sandstones. The mode of origin of flint or chert is not definitely known. It is certainly formed by the action of water, but the exact method is in dispute, and was probably different for different deposits. Other sedimentary rocks which were deposited under special conditions and which have a comparatively small distribution are gypsum, salt, and coal.

It is easily seen that the gravel and sand, which now form the conglomerates and sandstones, would be deposited near shore or where there was sufficient action by waves or currents to carry the coarse material in suspension, while the finer particles of mud would be carried out farther and deposited in more quiet waters. Some lime from shells would be deposited with the gravel, sand, and mud, but the quantity would be so small in comparison with that of the other materials that it could scarcely be noticed. It would be only in clear, relatively quiet water that pure, or nearly pure, lime mud would be formed.

From the way in which these different rocks are formed, it is evident that all three kinds of rock would be formed at the same time, that is, at the same time that gravel and sand were being deposited near shore, clay mud would be deposited farther from shore where the waters were more quiet, and lime mud would be forming farther out in the quiet, clear water. This is shown in fig. 1. When the sea level is at *AB*, gravel is deposted near shore and sand from *A* to *a*, mud from *a* to *b* and lime mud from *b* to *c*.

The different materials would naturally grade into each other laterally, that is, some fine sand would be deposited with the mud

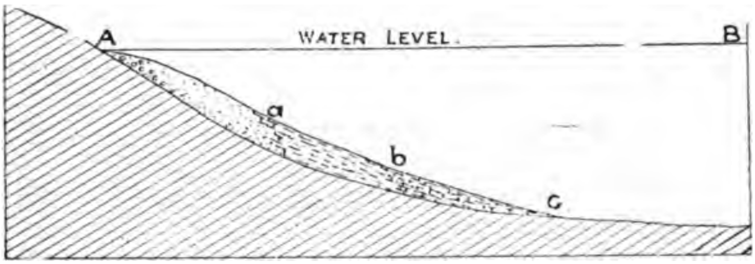

Fig. 1.—Diagram illustrating the simultaneous deposition of sand, mud and lime mud near a shore.

and some mud and extremely fine sand with the lime mud. It is also evident that changing conditions such as deepening of the water, elevation of the land, or a change in the direction of the ocean currents might cause a change in the nature or the distribution of sediments. Thus in fig. 2, when the water level was at *ab* gravel or sand would be deposited over the area *ac,* mud over *cd,* and lime mud over *de.* A change in level bringing the water level to *AB,* would cause sand to be deposited over *AC,* mud over *CD,* and lime mud over *DE.* We might thus have a layer of sand overlaid by a layer of mud or of lime mud, and mud overlaid by lime mud. A change of shore line in the opposite direction would deposit sand above mud, mud above lime mud, and lime mud farther out on the sea bottom. Any succession or number of successions of the three or any two of the three might be produced by varying conditions.

A greater change in the level of the sea might cause a great area of the sea bottom to become land, and the layers of gravel, sand, mud, and lime mud would then become hardened by the pressure of the overlying layers and by chemical changes and would be cemented to form conglomerate, sandstone, shale or slate, or limestone respectively.

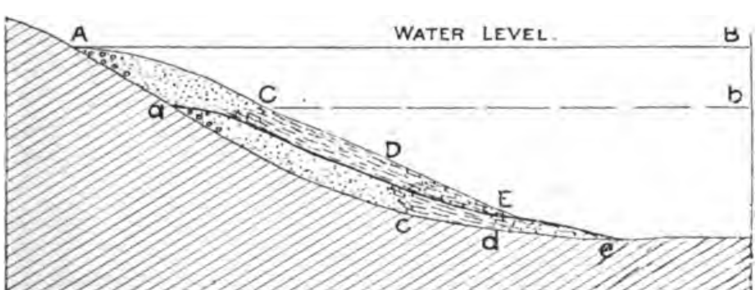

Fig. 2.—Diagram illustrating the effect of change of sea level on the succession of deposits at a given place.

As soon as the region became land the air and the water would begin their work of breaking down and carrying away the rock. While both agents are active the water is the more important. Running water is the great agent for carrying rock material from the land surface. Water also assists in the removal of rock by dissolving it and carrying it away in solution. The cementing material of sandstones is dissolved and the sandstone crumbles into sand which is easily washed away. This action would soon form hills and valleys so that a rough land surface would be developed. A further change in the sea level might bring this surface below the sea when it would again receive deposits as before. The earlier and

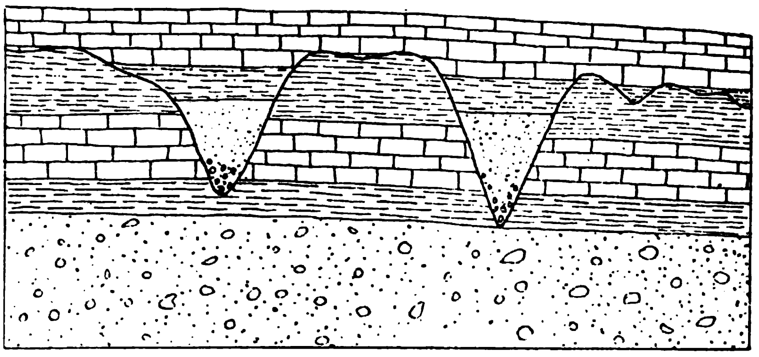

Fig. 3.—Diagram showing an unconformity.

later deposits would, however, be separated by a break or uneven surface—the old land surface. This condition is known as an *unconformity,* and is illustrated in fig. 3 where the irregular line represents an unconformity.

STRUCTURE OF ROCKS.

From the description of the mode of formation of the sedimentary rocks, it is apparent that the rocks would be deposited in a horizontal or level-lying portion or would be slightly inclined if deposited on a sloping sea bottom. It is seldom, however, that rocks which have been exposed as land for a long time remain in this level position. The earth is apparently growing smaller and this contraction causes wrinkles or folds to appear in the rocks of the surface in the same way that the skin of an apple becomes wrinkled as the apple dries up. These folds are not caused by pressure from beneath but from the sides. The method of their formation may be shown by grasping a number of sheets of cardboard or heavy paper by the ends and then pressing the hands together. A slight pressure will make only a simple bend in the paper

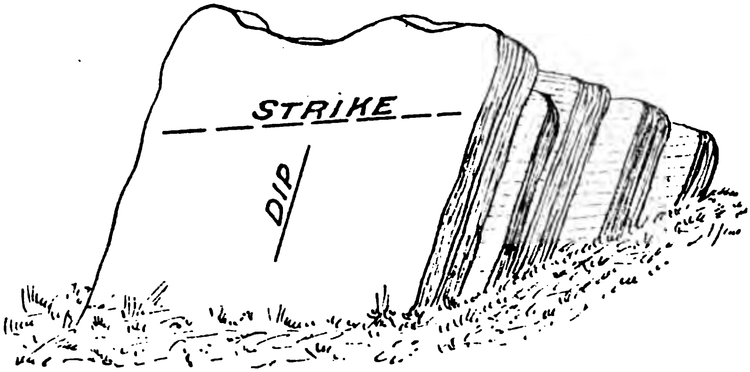

Fig. 4.—Diagram illustrating dip and strike.

so that a portion of it is inclined to the rest. A stronger pressure will force the paper into a well developed fold—a trough or crest as the case may be—and a still stronger pressure may cause more than one fold to be formed. If the paper is very stiff and the pressure sufficiently great some of the sheets may break and the broken ends be shoved past each other.

As has been said, the rocks which form the surface of the earth have almost everywhere been subjected to this lateral pressure and have been more or less folded, so that they are not level-lying but have an inclination or slope away from the horizontal. This slope or inclination is called the *dip*. The line along which a bed comes to the surface is the *outcrop* and the general direction of the line at right angles to the dip is the *strike*. (fig. 4). Where the surface rocks dip in one direction for a long distance the structure is known as a *monocline*. When the dip changes in short distance, that is when the rocks are in folds, two forms of structure may result, an upfold or arch, known as an *anticline* and a downfold or trough. known as a *syncline*. (fig. 5). Both anticlines and synclines are usually much longer than they are wide but in some cases the length and breadth are about equal. An anticline of this sort is called a

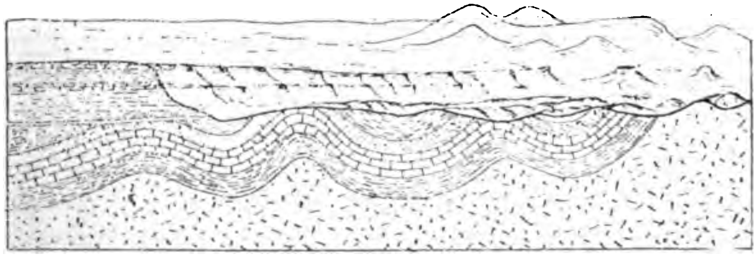

Fig. 5.—Diagram illustrating anticlines and synclines in section with landscape behind. (U. S. Geol. Survey.)

dome and a syncline is called a *basin* or *saucer-shaped* structure. Any one of these types of folds may vary greatly in size—some folds are much less than a mile in length, while others are many miles in both length and width. The steepness of the dip also varies. In some cases the rocks are standing on edge or have been overturned and in others the dip is so slight as not to be visible, so that the elevation of the ledge of rock at different places must be determined to find the direction and amount of the dip.

In some localities where the folding is very sharp, or where the rocks are under a stretching force rather than a pressure, the rocks have been broken along some lines and the rocks on the opposite sides of the break have moved upward or downward with reference to each other. In some cases the blocks have slipped laterally along the break as well as up or down. Such a break as this is called a *fault* (fig. 6.)

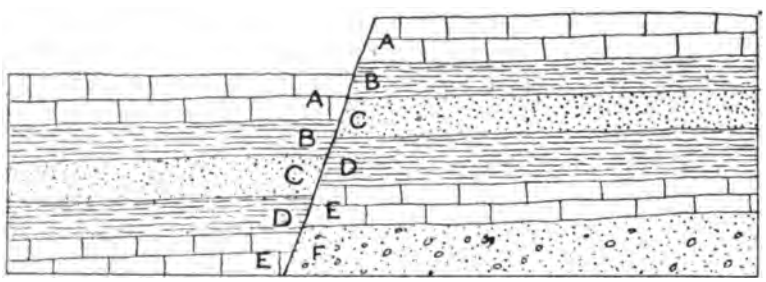

Fig. 6.—Diagram of a fault.

So far as our knowledge goes at present, the structure of the rocks is of prime importance in the accumulation of oil and gas and the meaning of the terms anticline, syncline, monocline, dome, and fault should be well understood by anyone interested in prospecting or in developing oil and gas fields.

The origin of the present surface forms, the hills and valleys, can not be considered fully in this connection, but it may be said here that the surface features very seldom bear any definite relation to the structure. The hills do not necessarily correspond to the anticlines nor the valleys to the synclines and a straight bluff does not usually indicate a fault, although it may do so. The presence of a fold is not shown by the elevation of the surface but solely by the dip of the rocks. This fact is well shown in figure 5.

AGE OF ROCKS.

Geologists divide the time included in the history of the earth into great eras, or periods of time, in which certain great events took place, in the same way that historians divide the history of the

United States into the era or period of discovery, era of colonization, Revolutionary era or period, and so on. In geology the great eras are established on the basis of the remains of life (fossils) found in the rocks which were formed during that era. The eras are divided into periods, generally on the basis of changes in the distribution of land and water, which caused minor variations in the character and distribution of life forms.

It has already been noted in the discussion of rocks and minerals that there are two great classes of rocks, the igneous, or those which have cooled from a molten condition, and the sedimentary, or those which were deposited as sediments from water or from the atmosphere. The sedimentary rocks which were deposited in water usually contain the remains of living organisms which were buried in the sediments at the time they were deposited, and which remain in the rocks to tell us of the kind of beings which inhabited the earth at the time the rocks were formed. Any remains of life forms which are found buried in rocks are called fossils. Among these fossils the remains of the animals living in the sea are the most common, since most of our sedimentary rocks were deposited in the sea or arms of the sea. However, land animals were often buried in swamps, or their skeletons washed down into the beds of streams and covered by sand or gravel so that they have been preserved. Naturally, only the hard parts of the animals are preserved, and animal fossils consist almost entirely of the shells of sea animals and the teeth and bones of land animals. From a study of these hard parts the trained observer can determine the nature and many of the characteristics of the animal to which they belonged. The science dealing with the ancient life of the earth, that is, the study of fossils, is called paleontology. Plants are also often preserved, the woody part being replaced by stone which preserves the original structure of the wood, or the impression of leaves, bark or stems remains in the sand or mud in which they were buried.

In the early part of the earth's history the animal and plant life included only the more simple forms, and the more complex forms developed from the simpler forms with the passing of time. Consequently if the study of the fossils in certain rocks shows that only the simpler, ancestral forms of life are present, these rocks can safely be said to be older than other rocks which contain the remains of more highly developed forms of animal or plant life. Paleontology, then forms the principal basis for the division of the earth's history into eras.

The great eras into which the earth's history is divided are as follows, beginning with the youngest:

(5) The Cenozoic (recent life) era.
(4) The Mesozoic (middle life) era.
(3) The Paleozoic (early life) era.
(2) The Proterozoic (earlier life), or Algonkian era.
(1) The Archeozoic (ancient life) or Archean era.

They are divided into periods as follows:

Eras.	Periods.	
Cenozoic	Recent	Quaternary
	Pleistocene	
	Pliocene	Tertiary
	Miocene	
	Oligocene	
	Eocene	
Mesozoic	Cretaceous	
	Lower Cretaceous or Comanchean	
	Jurassic	
	Triassic	
Paleozoic	Permian	
	Pennsylvanian	
	Mississippian	
	Devonian	
	Silurian	
	Ordovician	
	Cambrian	
Proterozoic or Algonkian		
Archeozoic or Archean		

The divisions of the Archeozoic and Proterozoic apply to only small areas and are not important in Oklahoma, Kansas or Texas.

The rocks deposited during each period of time are called a system of rocks, and the same name is applied to the system as to the period. For example, the Pennsylvanian system includes all the rocks which were deposited in the time included in the Pennsylvanian period. The names of the periods of the Paleozoic era are taken from places where the rock systems were first studied, or where they are well developed. The names Cambrian, Ordovician, and Silurian are taken from Wales; Devonian comes from Devonshire, England; Mississippian and Pennsylvanian from the Mississippi river and the state of Pennsylvania; and Permian from Perm, a province of Russia. The name Triassic comes from the three-fold division of these rocks in Germany where they were studied many years ago; Jurassic comes from the Jura Mountains in France and Switzerland, and Cretaceous from the Latin word "Creta" meaning chalk and refers to the famous "Chalk Cliffs" of England. The names of the periods of the Cenozoic era have reference to the character of the fossils and the relative abundance of living species.

To say that rocks are of Pennsylvanian age simply indicates that they are of the same age (were deposited at the same time) as the great coal-bearing series of rocks in Pennsylvania, or to say that they are of Cretaceous age indicates that they were deposited

at the same time as the rocks forming the great Chalk Cliffs of England.

In the Mid-Continent fields (Kansas, Oklahoma, and Texas) the rocks range in age from Archeozoic or Proterozoic to Recent. All the systems of the Paleozoic, the Mesozoic, and the Cenozoic, are found, although some of them have only a very limited distribution and do not occur in the immediate vicinity of any of the oil fields.

The systems of rocks are divided into smaller groups known as formations. A formation is defined as a mappable unit, that is a layer of rock or group of layers which extends entirely across the area under consideration and has sufficient width of outcrop to be mapped. Formations may consist of single ledges or beds of rock but commonly are made up of two or more closely related beds.

The separate beds are sometimes called members. Thus, the principal oil sands of the main oil and gas field of Kansas and Oklahoma may be considered as members of the Cherokee formation. The formations and members are usually named from the place where they are best developed or where they were first studied. The Pitkin limestone which outcrops east of Muskogee and Ft. Gibson is an example of a formation consisting of only one kind of rock. The Ft. Scott formation, known to the drillers as the Oswego, is usually called the Ft. Scott limestone, but really consists of two limestones separated by a shale. Formations may vary in thickness from a few feet to thousands of feet. Thus the Chattanooga shale in northeastern Oklahoma is not over 50 feet thick while the Arbuckle limestone in the Arbuckle Mountains is over 5,000 feet thick. Formation names are a great convenience since they provide means of designating certain beds of rock without repeating extended descriptions. They are necessarily used extensively in the description of the geology of any region.

CHAPTER II.

NATURE, ORIGIN AND ACCUMULATION OF PETROLEUM AND NATURAL GAS.

NATURE OF PETROLEUM AND NATURAL GAS.

Natural gas, petroleum, and asphalt or mineral paraffin are all closely related substances forming the different phases of a series of chemical compounds composed of hydrogen and carbon. The simpler compounds of this series are gases while the more complex are liquids and solids. Neither gas, oil, nor asphalt are simple compounds but are mixtures of different members of this series of hydrocarbons. This condition is responsible for the large number of products obtained from petroleum since, in refining, the compounds can be separated from each other and as they form a continuous series almost any number of products can be made by separating the petroleum into different fractions by distillation.

As has been indicated, natural gas is a mixture of simpler members of the hydrocarbon series which are gaseous at ordinary temperatures. Gas occurs in greater or less quantities with all petroleum. It is colorless, and has a slight odor. The heavier members of the gaseous hydrocarbons are very nearly related to the lighter members of the liquid ones and may be changed to liquids by pressure at low temperatures. This accounts for the manufacture of gasoline from natural gas which is becoming an important industry. The gas which is given off from oil wells, known as casing-head gas, is composed of the heavier gaseous hydrocarbons and is especially adapted to the manufacture of gasoline.

Petroleum is composed of the hydrocarbons that are liquid at ordinary temperatures and pressures and of the hydrocarbons that are solid ordinarily but which are dissolved in the liquid hydrocarbons. The physical properties of petroleum from different fields and even from different wells in the same field vary widely. Some oils are thin and contain considerable volatile constituents, while others are thick and viscous. In color the oils range from almost colorless through a variety of tints of brown and green to black. The Pennsylvania oils are mostly of an amber color, those of Oklahoma are generally dark green to black and those of California are generally dark reddish brown to black. The specific gravity ranges from 0.771 to 1.06 according to Redwood. That is, the weight of a given volume of oil varies from 0.771 to 1.06 times that of an equal

volume of pure water. In general the lighter colored oils have the less specific gravity and produce, when refined, the greater amounts of burning oil and less of the heavy lubricating oils and residuum. The gravity of petroleum and its products is usually given in degrees of the Baume scale, which is an arbitrary scale.

The proportion of the lighter oils, gasoline and kerosene, to the heavier oils which are fitted only for lubricating and fuel oils varies very widely. The nature of the base or solid hydrocarbons dissolved in the oil also varies. Oils are known as asphalt or paraffin-base oils according to which substance predominates in the base. Some oils contain either a pure paraffin or a pure asphalt base, but much more commonly the two substances occur in the same oil. The Pennsylvania, Lima-Indiana, and Mid-continent oils are principally paraffin-base oils, while those of California and the Gulf Coast are mostly asphalt-base oils.

The properties and composition of the Mid-continent oils are considered more fully in the section on that subject.

CONDITIONS OF OCCURRENCE OF PETROLEUM AND NATURAL GAS.

General Statement.

All the known deposits of oil and gas occur in sedimentary rocks, and the majority of the occurrences are distant from areas of igneous rocks. Deposits of considerable size have been found in all sorts of sedimentary rocks but limestones and sandstones contain oil and gas much more commonly than do shales. This is probably only because the limestones and sandstones are more open and porous and so offer an opportunity for the oil and gas to collect. So far as observations go it is in the pores and small spaces of the rocks that these substances occur and there are probably no "lakes" of oil—that is no large caverns filled with oil. The advantage of "shooting" oil wells depends on this fact. Often when a small quantity of oil is found in a well, drilling is stopped and a heavy charge of nitroglycerine is lowered to the bottom of the well and discharged there. This has the effect of shattering the rock and opening it up so that the oil can flow through more rapidly and greatly increases the production of the well.

Almost invariably there is a layer of a tight, close-grained rock immediately above the porous rock. This is known as the cap rock.

In the Mid-continent field the principal oil and gas pools are closely related to the presence of certain structures, notably the anticlines and monoclines. It cannot be said that all the developed fields are on anticlines or that every anticline contains oil and gas in sufficient quantity to pay for drilling. In some of the developed fields the structure is so gentle that it can be determined only by

extremely careful detailed work so that the relation of the accumulation to the structure cannot yet be definitely stated.

In some regions, in Mexico for example, the occurrence of oil seeps or springs seems to be definitely related to the presence of large bodies of oil beneath the surface. Oil seeps of this kind, however, are rare in the Mid-continent fields and only a few of the pools had surface showings of oil or gas. All the important deposits of oil and gas occur in rocks which contain abundant organic remains or are closely associated with rocks containing such remains.

Oil and gas are usually but not always associated with strong heads of salt water.

There is no general relation between oil fields and streams, coasts, mountains, or other surface features unless these features result from the structures that control the accumulation of the oil.

It should be repeated that these statements are general and are intended to apply only to commercially important bodies of oil and gas and especially to the conditions in the Mid-continent field. Small quantities of either oil or gas or both together or of closely related substances may be found under almost any conditions, but the statements made above will hold for the principal deposits and especially for those of this field.

Theories of Origin.

The origin of petroleum and natural gas has been a question causing much controversy ever since these substances became of economic importance. Since this subject is of prime importance in connection with the related subjects of migration and accumulation and also in connection with the prospecting for oil and gas it is considered somewhat fully.

The theories of origin fall into two classes—the organic and the inorganic.

The *inorganic theory* postulates that the deposits of oil and gas have been formed by the interaction of various inorganic or mineral substances. Some of the reactions which have been suggested as possibly producing the bituminous substances are:

(1) The action of water on the alkali metals at high temperature would produce acetylene which could polymerize to form petroleum.

(2) The action of carbondioxide and steam on iron at high temperatures.

(3) The action of water on carbides of different metals would form acetylene which could polymerize to form petroleum. Carbides do not exist in the surficial part of the earth's crust but may be present at depths.

(4) The interaction of volcanic emanations which contain carbon in the form of carbondioxide and some hydrocarbons, or the action of such emanations upon the rocks.

(5) The presence of carbon and hydrogen is known in the outer envelopes of some of the heavenly bodies. It is thought that as the earth cooled from a nebulous mass these substances would unite to form hydrocarbons which would be generally distributed throughout the mass of the earth. This idea depends on a theory of earth origin to which there are many strong objections.

(6) The action of acetylene and hydrogen on nickel gives an oil resembling Pennsylvania petroleum; acetylene alone acting on nickel gives an oil resembling the Russian petroleums.

The *organic theory* postulates that petroleum and related substances have been produced by the slow decay of plant or animal matter (or both) which was carried down by and buried in the mud which formed the rocks in which or near which the bituminous substances are now found.

There are certain objections to both of these theories which may be briefly outlined as follows:

Objections to the Inorganic Theory. (1) The conditions postulated in all forms of this theory are not known to exist in the earth, and it is highly improbable that most of them do exist. (2) All the reactions require high temperatures, and, if they take place at all, must do so at great depths or near igneous activity which would produce the required temperatures. The known important petroleum deposits are of moderate depths and generally far removed from igneous activity. So, even it if is granted that these reactions could take place, it is necessary to assume that the bituminous products have migrated for immense distances, both laterally and vertically, if we consider that the commercial deposits of oil and gas have resulted from such action. The mechanics of the migration of oil and gas make it seem impossible that migration can take place through such distances.

Objections to the Organic Theory. (1) The principal objection which has been made to the organic theory is that it requires the presence of too much organic matter in the rocks to account for the larger deposits of petroleum. This objection, however, will not stand since it has been shown the shales in some of the largest fields contain more than enough bituminous matter to account for all of the oil. If it is assumed that a thickness of 1,000 feet of rocks contribute to a certain oil horizon, and that the bitumen is all accumulated, a bituminous content of only one-fifth of one percent is necessary to account for the oil contained in the richest spots yet tapped. It is very improbable that so great a thickness of rocks contributes to a given deposit of oil, or that the bitumen is all accumulated as oil. However, many shales and some sandstones

and limestones contain such high percentages of organic matter that only a moderate thickness need contribute and only a small portion of the organic matter need be accumulated as oil to account for the acre yields of any of the fields yet developed.

The second objection to the organic theory is that the decay of complex organic material would give substances much higher in sulphur, nitrogen, and phosphorus than is petroleum. The researches of Engler, however, have shown that under the conditions which exist in nature the decomposition of organic matter in salt water probably takes place in two stages—a comparatively rapid decay in which the products of the nitrogenous compounds are given off, together with the sulphur and phosphorus, leaving only the fatty substances to be carried down with the mud and to undergo the further decomposition. The products of the distillation of such fatty substances in the laboratory closely resembles petroleum.

In spite of there being some features of the accumulation of immense bodies of petroleum from organic matter which are somewhat difficult of explanation, it may be safely said that this theory is generally accepted at present.

The evidence in favor of it may be briefly summarized as follows:

(1) The distillation of fatty substances under pressure gives products almost or quite identical with petroleum.

(2) The universal association of bituminous rocks (the bitumen being evidently of organic origin) with deposits of petroleum and the absence of such deposits in localities where all the other conditions seem to be favorable but where the rocks are lacking in known organic remains.

(3) The distance from centers of igneous activity and the shallow depths at which the great deposits of petroleum occur.

(4) Many of the great oil fields occur in regions in which the rocks are very little disturbed and where there is no reason to believe that there is opportunity for the oil to have moved upward from great depths.

(5) The ample supply of organic material in most of the sedimentary rocks to account for any known accumulation.

(6) Petroleum is optically active—that is, it is able to rotate the plane of polarized light. The artificial petroleums prepared by the distillation of organic material have this power but those prepared from inorganic materials do not.

If the organic theory of the origin of petroleum be accepted it becomes of interest to determine what types of organisms went to form the accumulation.

It is evident that land animals could have played no part in the formation of petroleum since practically all the deposits are in ma-

rine rocks in which land animals could have been buried only by extremely rare accidents.

Land vegetation is occasionally carried considerable distances from shore and might take part in the formation of petroleum. It seems, however, that the woody plants would go to form lignite or coal rather than petroleum. The small amounts of vegetable fats derived from the decay of such plants may have entered into the formation of the bitumens but, as a whole, the contribution of land plants may be considered negligible.

The larger sea animals—fish, amphibians, reptiles, mammals, and shell fish of all kinds—may also be considered as unimportant in this connection. When one of these animals dies the carcass is almost certain to be eaten by some other animal. If it is not eaten, the fats from its composition will rise to the surface and will be widely disseminated. In some situations there might be considerable accumulation of the remains of such animals and all petroleum deposits have almost certainly received some contribution from the larger animals, but the proportion of petroleum derived from this source must be small.

There remain the smaller sea animals—such as the corals, the foraminifera and the other single-celled animals—and the sea plants. The products from these life forms are more likely to escape immediate destruction and, in favorable situations, are known to collect in considerable quantities. The comparative importance of the smaller animals and the plants as a source of petroleum is open to question. It is very probable that the proportions of plant and animal matter varied considerably in the rocks from which the different deposits of petroleum were derived and that the difference in the characters of petroleums in different fields is due, in part at least, to the difference in the character of the organic matter buried with the rocks.

The Migration of Oil and Gas.

As has been shown, the inorganic theory of the origin of petroleum makes it necessary for the oil and gas to have migrated great distances to be found in the places they now occupy. If the oil and gas are derived from organic matter buried in the sedimentary rocks, only a short migration is necessary but in any case some movement of the bituminous substances is necessary to form the enormous accumulations which exist in certain beds of rock.

Most accumulations of oil and gas are in sands or sandstones, and it seems certain that the proportion of organic matter buried in these rocks is insufficient to account for such quantities as are present. We must account for the transfer of the bituminous substances from neighboring rocks, into the rocks in which they are

now found and in some cases at least, for some little distances in these rocks.

The ultimate source of most of the oil in the larger accumulations must have been in the bituminous shales which are associated with the oil-bearing sands. In these shales the oil was in a finely desseminated condition and distributed fairly uniformly throughout the mass of the shale of mud. The wet mud in consolidating would be greatly reduced in volume and much of the liquid matter would be forced out. Both water and the bituminous matter would be forced out but, as the distance between the individual clay particles was reduced by the consolidation, the water, on account of its greater surface tension, would be held much more strongly than either oil or gas particles, so that the latter substances would be forced out into the coarser grained rocks in greater proportion than would the water. It has been demonstrated both mathematically and experimentally that this action is sufficient to account for the transfer of oil and gas from fine-grained shales to coarser rocks with which they are associated.

The cause and nature of migration and the distance to which oil and gas may migrate within a porous bed are subjects on which there is much difference of opinion. The earlier opinion was that the difference in specific gravity between the oil and gas and the water, with which they are usually associated, was the principal cause of the movement. It has been shown, however, that this is insufficient of itself to cause migration, although it is possible that it may be a determining factor where the other factors are nearly balanced. The most recent researches seem to show that we must depend mainly on the difference between the surface tension or capillarity of the different substances as the principal cause of migration. The water on account of its higher surface tension forces the oil and gas from the finer spaces into the coarser. Within a coarse-textured bed the difference in specific gravity may cause some movement. It has also been suggested that the slow movement of underground water assists in the accumulation of large bodies of oil and gas. Small earth movements such as earthquake tremors and the small tidal movements may have some effect on the starting of the migration. The whole problem is extremely complex and it is certain that we must look to a number of factors which produce and influence the migration, rather than to a single cause.

**Accumulation.*

Granting that oil and gas can and do move in the rocks, there are several conditions that must be fulfilled before there can be an

*The anticlinal theory was developed principally by I. C. White and Edward Orton. A review of the early publications on this subject is given by M. R. Campbell in Economic Geology, Vol. 6, No. 4., pp. 363-395, 1911.

accumulation of commercial importance. These may be briefly enumerated as follows:

(1) A bituminous rock as a source for the oil. This has already been mentioned. The probabilities are that bituminous shales are the source of practically all the oil in the Mid-continent fields. During deposition, the mud would have a greater power of carrying the organic matter down with it than would the sand or lime particles. The proportion of organic matter would also be higher in mud than in sand on account of the much more rapid accumulation of the latter.

(2) A porous rock to act as a reservoir for the oil and gas. This is a sandstone in most cases. Sandstones are deposited in comparatively shallow water and vary considerably in thickness and character within short distances. The variation in the size of grain is one of the important features of oil-bearing sands. The finer the grain of the sand, the less the pore space, and consequently the less the total amount of oil contained per volume of sand. Migration is naturally slower in the finer-grained rocks and wells producing from them usually have smaller initial productions and are longer lived than those in coarser-grained rocks. An ideal sand is one of moderate thickness, and of medium grain, and with sufficient cementing material to cause it to stand up well but not sufficient to occupy much of the space between the grains.

Conglomerates may be regarded as very coarse sandstones so far as they act as oil and gas reservoirs. Limestones, where sufficiently porous, act as reservoirs. The porosity may be due to the original texture; to dolomitization which increases the pore space; to erosion and solution; to faulting or jointing which opens cavities in the limestone, and to the effect of solutions from igneous intrusions. The porosity of limestones may be very high, as much as 30 or 40 per cent. Shales often contain a high percentage of bituminous matter but are usually so fine-grained that oil is retained in them. Oil is found in some places in joint cracks in shale, and the porous diatomaceous shales of California have been very productive. It is probable, however, that most of the oil reported as coming from shale comes from sandy streaks in the shale or from a sand immediately under the shale. Porous or weathered igneous rocks act as reservoirs in some cases. The only known example in the Mid-continent fields is at Thrall, Texas.

(3) A cap rock to prevent the oil from migrating directly upward to the surface. This is usually a shale or other fine-grained rock. The cap rock is essential to the accumulation of oil and gas, but its character has little or no effect on the accumulation, except in the cases where it is a bituminous shale which, besides acting as a cap rock, may be the source of a considerable portion or of all of the oil and gas.

(4) The presence of water in the rocks is a controlling factor in the accumulation of oil and gas. Its effect in driving these substances from the finer to the coarser pores in the rock has been noticed.

(5) Favorable structural conditions or variations in the thickness and porosity of the beds which produce the same effects as favorable structures. This feature is so important that it is considered in a separate section.

Structural Relations.

Observation of the developed oil fields in Pennsylvania, Ohio, and West Virginia convinced many of the observers that there is some definite relation between the accumulation of oil and gas and the structure of the rocks. It was determined that the principal oil and gas pools lay along the crests of the anticlinal folds; therefore, the theory of accumulation based on these observations has become known as the anticlinal theory. This theory has been of great value in locating prospective oil and gas regions, but the attempt to apply it to other fields where the geologic conditions are not similar to those where it was originally applied has not always been successful. Various changes have been made in the theory, but the fundamental part of the theory—that the accumulation of oil and gas depends on the structure—is still generally accepted.

The anticlinal theory is, in brief, that oil and gas were originally widely disseminated throughout the formations in which they are found, or in contiguous formations, and their segregation is believed to be due to the different specific gravities of oil, gas and water. If a porous stratum contains all these substances, when it is tilted by geologic causes, they will arrange themselves according to specific gravity; the gas, being lighter, will be driven into the higher parts of the stratum (toward the crest of the anticline), the oil will

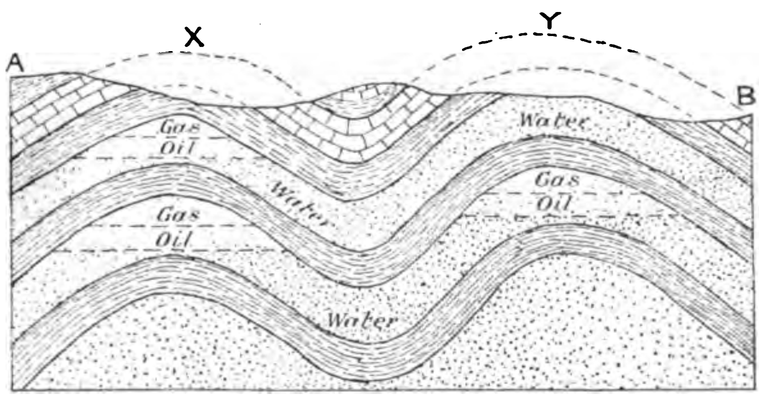

Fig. 7.—Diagram representing the accumulation of oil and gas in anticlines.

be floated on top of the water, while the water occupies the lower portions of the stratum (those nearest the syncline).

These conditions are represented in the accompanying figure.

In this figure, as in all others in the book, sandstone is represented by the dotted pattern, shale by the closely ruled pattern and limestone by the block pattern. The line *AB* represents the present land surface and the broken lines represent the strata which have been removed by erosion. The oil and gas are shown collected in the sandstones under the crests of the anticlines at *X* and *Y*. At *Y* the shale has been removed from over the upper sandstone, allowing the oil and gas to escape.

As work progressed in areas outside the Pennsylvania and West Virginia fields it was found that the variations of structure made it necessary to modify the anticlinal theory in some respects. The presence of a true anticline has been shown not to be necessary for accumulation, but any structure or tilting of the rocks which will cause the oil, gas and water to arrange themselves in the order of their specific gravities will suffice for the accumulation if the oil and gas are sealed in from the surface. On this account a new classification of oil fields based on structure has been prepared by F. G. Clapp (Economic Geology. Vol. V, No. 6), as follows:

I. Where anticlinal and synclinal structures exists.
   (a) Strong anticlines standing alone.
   (b) Well defined anticlines and synclines alternating.
   (c) Monoclinal slopes with change in dip.
   (d) Terrace structure.
   (e) Broad geanticlinal folds.
   (f) Overturned folds.

II. Domes or quaquaversal structures.

III. Sealed faults.

IV. Oil and gas sealed in by asphaltic deposits.

V. Joint cracks.

VI. Surrounding volcanic vents (or igneous intrusions.)

Almost all the important fields belong to some division of Class I, among them being the Appalachian, Mid-continent, Illinois, Indiana, Wyoming, Colorado, northern Louisiana, northern Texas, and some of the California fields in this country, and the Russian, Austrian, Burma, and Borneo fields in the eastern hemisphere. Of the different subclasses, the second is probably the most common, containing with a few minor exceptions the Appalachian field in Pennsylvania, West Virginia, and eastern Kentucky, the southern Indiana and Illinois field, the Kansas and Oklahoma fields, the Caddo field in northern Louisiana, the north Texas fields, and those of Colorado, Wyoming, and Montana. The conditions in these fields are shown diagrammatically in fig. 7.

Subclasses *c* and *d* may be considered together since *d* is only an extreme type of *c*. These structures are sometimes called arrested anticlines since the forces were apparently the same as those forming anticlines, but not strong enough to reverse completely the normal dip of rocks with a monoclinal structure, but merely to lessen the dip locally or to flatten the rocks out. The conditions are shown diagrammatically in fig. 8. Some of the important pools of northern Oklahoma and Kansas represent this type of structure although most of them belong to subclass *b*.

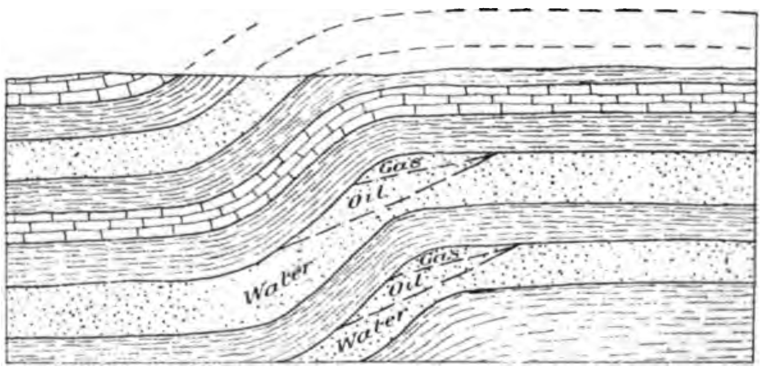

Fig. 8.—Diagram showing the accumulation of oil and gas in a terrace or arrested anticline.

The last two subclasses are probably not represented in Oklahoma. The fields in Ohio and Indiana around the Cincinnati arch or geanticline belong to subclass *e*.

Class II is represented by the pools in the coastal plain of Texas and Louisiana. Class III occurs in some of the California fields. It is possible, although scarcely probable, that this condition occurs in the Ouachita Mountains in the southeastern part of Oklahoma. The conditions are represented in the diagram of a fault (fig. 4.) Oil contained in the sandstone layer would be sealed in by the fault passing through the overlying shale layer, and would collect near the fault line if the sandstone dipped away from the fault, which would usually be the case on one side or the other. Faults of this type exist in the region mentioned and the asphalt deposits prove that oil was once present in the rocks, but whether it all escaped or whether part of it is sealed in along some of the faults is problematic. Class IV is possibly represented in Oklahoma by some small deposits giving rise to the oil springs or seeps in the Arbuckle Mountain region. It is not at all probable that the deposits are large enough to be of any value. Small faults have a pronounced effect on the accumulation in several fields in Oklahoma and probably in Kansas and Texas, but their influence seems

to be due more to the alteration in the water conditions than to the sealing effect. Class V is not very important, occurring, so far as known, only in Canada. Class VI does not occur in the Mid-continent fields. Some of the large Mexican fields probably belong to this class.

It seems to the writer that one other condition should be included in this list, which, while not strictly a structural condition, should have the same effect as inclined strata on accumulation. This is the local thickening of sands or the occurrence of short, thick lenses of sand in shale. The conditions are shown diagrammatically

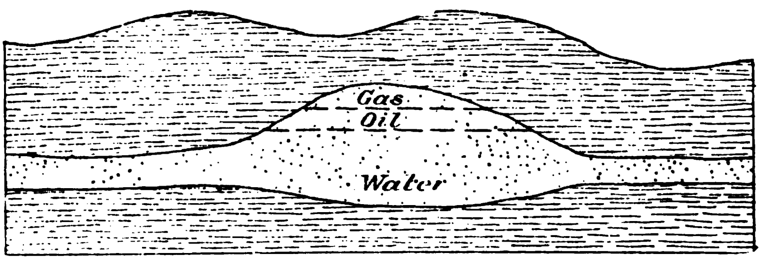

Fig. 9.—Diagram illustrating the accumulation of oil and gas in a lens of sandstone in shale.

in the accompanying sketch (fig. 9.) In this case the oil and gas would certainly collect in the top of the arch made in the shale by the lens of sand, the gas at the top and the oil lower down. This local thickening of the sands or occurrence of such lenses may or may not give any surface indications of their presence and may account for some oil and gas pools where no surface structure can be made out, as in the Cretaceous area along Red River in southern Oklahoma.

A factor which is of extreme importance in the consideration of accumulation by any type of structure is the difference in porosity of the same sandstone in different localities. If a sandstone is studied along its outcrop it will be found to vary somewhat in character from place to place. In one place it may be composed of fairly large grains of sand loosely cemented together, while a short distance away it will be very fine-grained and well cemented so that there is very little pore space. It is only reasonable to presume that such variations also exist in the sandstones underneath the surface, and this variation is believed to account for the occasional finding of dry holes which are in proven territory and which may be entirely surrounded by producing wells. It is supposed that the dry holes encountered a non-porous or tight place in the sandstone, while the producing wells penetrated more open, porous places. The variation in production of wells of equal depth located near each other is explained in the same way. In general

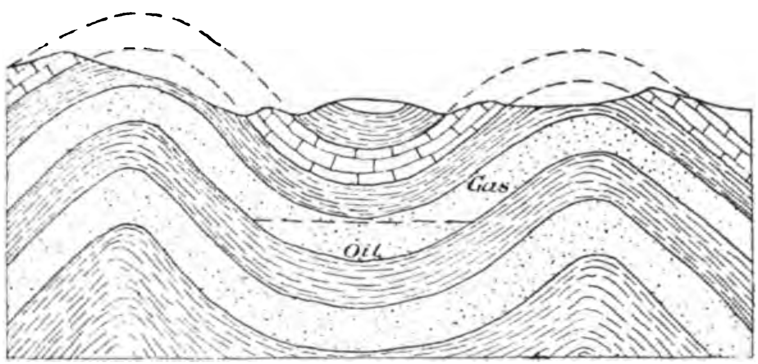

Fig. 10.—Diagram illustrating the accumulation of oil in syncline in the absence of water.

the more open and porous the sand, the greater the amount of oil contained and the more rapidly the oil can be given up from the sand around the bottom of the well. This also accounts for the fact that very often wells of phenomenally large initial production are not as long-lived as those with a smaller production, since the more rapidly the oil can pass through the sand the sooner will the supply be exhausted. The shooting of oil wells is based on the same fact, as the effect of the shooting is simply to loosen up the sand so that the oil can pass through it more readily. A notably coarse body of sand entirely surrounded by finer sand would serve as a collecting ground and might contain a considerable deposit of oil without giving any surface indications.

Still another feature needs to be considered in this connection. All the statements previously made concerning the effect of structure on accumulation are based on the presence of water with the oil and gas. When no water is present the oil and gas, instead of being collected in the anticlines or corresponding structures, seek the synclines or lower parts of the structure governing the accumulation, the oil in the bottom of the syncline and the gas higher on the slope as shown in the accompanying diagram. (fig. 10). This condition is not known to exist in the Mid-continent fields although it probably does.

Effect of Metamorphism.

It is well known that in regions of great metamorphism commercial deposits of petroleum are lacking. It is evident that if deposits of petroleum are included in rocks that the petroleum will be subject to the same processes as the rocks themselves and we may naturally expect that it will be altered to a degree corresponding to the degree of metamorphism of the limestones, shales and sandstones with which it is associated.

In many fields petroleum deposits occur in the same series of rocks with veins of coal, and David White* has called attention to the relationship between the degree of metamorphism of the coal beds of certain regions to the character of the other bituminous substances contained in the same series of rocks.

Briefly stated, his observations are that in regions in which the coals are of very low grade (with low fixed-carbon and high volatile matter content) the oils are also very low grade, as for example the Gulf Coast and the bulk of the California oils; with increase of fixed-carbon in the coals, we find continually higher grade oils until the percentage of fixed-carbon reaches 60; in regions where the fixed-carbon content is between 60 and 65 or 70 per cent, there may be some gas, but no oil; and where the fixed carbon content is above 70 per cent there is little probability of there being commercial deposits of gas and there is no oil.

The change from peat to lignite and through sub-bituminous, bituminous, semi-bituminous and semi-anthracite to anthracite is due to the progressive breaking down of the complex organic compounds, with the formation of simpler solid compounds and to the escape of volatile matter. In a parallel series of changes, the highly complex organic compounds of low grade petroleums are broken down into simpler forms giving high grade oils and natural gas. In the process of metamorphism the volatile oil-forming matter will escape from the sandstone and shale layers just as the volatile matter escapes from the coal.

Or, in other words, the percentage of fixed-carbon in coal is an index of the amount of metamorphism which the rocks have undergone, and at the same time, the same processes cause the alteration from low grade to high grade oils and gas and finally the expulsion (or escape) of all the volatile matter of petroliferous deposits.

White's observations were based in part on the Mid-continent fields. Beginning in southeastern Kansas there is a gradual increase in the percentage of fixed-carbon in the coal to the south and southeast into Arkansas. The oils of Kansas are of notably lower grade than those farther south and west. In the territory to the southeast and east of a line drawn through southeastern Muskogee county and McIntosh, Hughes and Pontotoc counties, the coals have a fixed carbon content greater than that given by White as limiting the occurrence of petroleum. So far only gas has been found in commercial quantities in this entire area.

White considers the various factors which may influence this metamorphism of petroliferous deposits, such as (a) migration of oil which may produce small deposits of high-grade oil in regions

*White, David, Some relations in origin between coal and petroleum: Jour. Wash., Acad. Sci., Vol. 5, No. 6, pp. 189-212, 1915.

of very little metamorphism, (b) the effects of intense local metamorphism, (c) the difference in the "sealing in" effect of different types of beds which may effect the escape of the volatile constituents and (d) the effect of difference in the character of the original organic material going to form the petroliferous deposits.

His theory is put forth as applicable to broad regional conditions rather than to local deposits and, in general, holds for the deposits so far discovered.

CHAPTER III.

THE PRODUCTION OF PETROLEUM AND NATURAL GAS.

In the present section an attempt is made to give a brief review of the methods and processes used in obtaining petroleum and natural gas. The subjects considered are prospecting and drilling The subjects of transportation, marketing and refining are noted only incidentally since they are highly technical and are of little interest to the general reader.

PROSPECTING.

From what has been said concerning the conditions of occurrence of oil and gas, and the generally accepted theories of their origin and accumulation, certain general rules concerning the prospecting for these substances can be deduced. The knowledge of conditions in developed fields is a great aid in determining the relations of the oil and gas pool to the nature of the rocks, both the surface rocks and those encountered in drilling, as well as to the structure of the rocks and to the surface features. The value of geology as an aid to prospecting is considered at some length.

Nature of the Surface Rocks—Many people are strongly of the opinion that the rocks immediately on the surface are related to the occurrence of oil and gas below, and there is, locally, quite a strong prejudice in favor of starting wells on top of limestone. In regard to this matter it may be said that the developments in the different fields of the country and even of the different pools in the Mid-continent fields prove that this idea is without foundation.

It has already been noted that all the important deposits of oil and gas occur in sedimentary rocks, limestones, sandstones, or shales. No deposits are known in igneous rocks or in rocks that have been so metamorphosed by heat and pressure that their original nature has been destroyed. In the Mid-continent fields this fact is of importance in small areas since most of the surface rocks are sedimentary.

In the Arbuckle and Wichita mountains, in Oklahoma and in the Llano-Burnet mountains and in trans-Pecos Texas, however, there are considerable areas in which the surface rocks are granite and closely related rocks. In these areas there is absolutely no use of prospecting oil and gas.

It is certain that holes started on the granite would encounter no other kind of rock in the depth to which drilling can be done.

In an area of sedimentary rocks a little consideration will make it possible to select the more favorable areas from the less favorable. Whether the organic theory of the origin of oil and gas be accepted or not, the fact remains that all important deposits of either substance are found in rocks which are strongly charged with organic matter or which are closely associated with such rocks. This is usually shown by the presence of fossils and by the prevailing dark colors of the rocks. The dark blues and greens and the blacks are due to the presence of iron in the reduced form, the reduction being due to the presence of organic matter, or in some cases, the color is due to the organic matter itself. In rocks in which very little or no organic matter is present the iron is in the oxidized form—iron rust—and gives the rocks a prevailing red color. A large area of red rocks too thick to be drilled through cannot but be regarded as a most unlikely region for oil and gas prospecting.

Similarly a region in which all the rocks within reach of the drill are either very near-shore or very deep-sea deposits is very unfavorable territory for prospecting. As noted under the discussion of the origin of oil and gas, it is only where mud is being deposited that sufficient organic matter is carried down with the sediments to produce commercial deposits of oil or gas. In regions, therefore, where the rocks within reach of the drill are made up of subaerial deposits, or of near-shore or basal sandstones and conglomerates, or massive limestones of deep-sea origin, prospecting cannot be recommended, no matter if favorable structural conditions are present.

It is not always possible to determine in advance of drilling precisely the nature of the rocks to be encountered but a thorough study of the general geology of the region will generally give a fairly accurate idea as to the general character of the section.

Very strongly metamorphosed sediments or those which are very steeply folded or are much faulted are not likely to contain oil or gas in quantity. The effect of metamorphism has been noted in the preceding section. Folding and faulting are generally accompanied by profound metamorphism, especially in the older rocks.

In rocks as young as the Tertiary, or even the Cretaceous, large quantities of oil and gas are found where the folding is steep, as in California and Wyoming, but in rocks as old as the Pennsylvanian, steep folding is generally accompanied by such pronounced metamorphism that oil and gas are no longer present in the rocks even if they were originally.

Relations of Oil and Gas Pools to Topographic Features.—The statement is often made that the indications in a certain territory or on a certain tract of land are favorable for oil and

gas because the land is near or lies parallel to a river or mountain range or some other topographic feature. The statement that all oil and gas fields lie parallel to some coast or stream is necessarily true, but is of absolutely no value in prospecting. For example, the fields or pools in northeastern Oklahoma having an east-west trend are nearly parallel to Arkansas river and those bearing north and south are parallel to the Verdigris. In fact, it would be practically impossible to locate a pool so that the trend would not be in a measure parallel to some stream in the vicinity. At the same time unproductive tracts would show exactly the same relation. The only case in which the course of a stream would really be related to the trend of an oil or gas pool would be where the course of the stream is controlled by the structure of the rocks and where the same structure is related to the accumulation of the oil or gas. In this case the shape or the trend of the oil pool would be due to the structure instead of to its following the course of the river. It may be said, therefore, that the presence or absence of a stream in a given area or the relation of a tract of land to its course is no indication as to the occurrence of oil and gas unless the course of the stream is controlled by the structure and in this case the indications may or may not be favorable on a given tract.

The relations of pools to mountain ranges are of the same nature as their relations to rivers. The structure of the mountain range often provides the necessary conditions for the accumulation of oil and gas and hence the long axis of the pool is often parallel to the direction of the ranges. The relation of the pool, however, is to the structure and not to the mountain range itself. If the rocks making up a mountain range are igneous or strongly metamorphic there will be no oil or gas in them any more than there will be in rocks of the same kind at a distance from the mountains, and if the rocks and the structure are favorable for accumulation in a region there will be oil and gas no matter what the relation to a mountain range may be.

In general, hills and valleys cannot be depended upon to give any indication as to the presence of oil and gas. In many developed pools, wells started on the hills are just as productive as those started in the valleys and vice versa. Other pools are on practically level land. There is no more ground for saying that a certain location should be a good place for prospecting because the surface looks like that of a developed pool than for saying that the same region is without oil and gas because the surface is very unlike that of another developed pool, or that it is very like another region which is known to be dry. In some instances the distribution of the hills and valleys depends on the structure and here, of course, the surface configuration may give some indication as to the more probable places to prospect. In the coal fields of the east-central part of

Oklahoma the anticlines are often worn down into valleys while the synclines stand up as ridges and hills. In this region it is wiser to prospect in the valleys than on the hills if no further investigation is made. Even in this locality, however, there are so many exceptions to the general rule and so many hills and valleys that are without relation to the structure that it is much better to work out the structure definitely before locating a test well than to depend upon the character of the surface alone.

"Oil Trends"—An idea that was held generally in the early days of the industry and which still has a number of adherents is that oil occurs along certain well developed trends or lines and that territory anywhere along certain well developed trends is favorable for prospecting. It is believed by many people that the country will eventually be developed between the Oklahoma field and the Gulf field in Texas and Louisiana. It is apparent that if this idea were carried to an extreme almost any region could be considered as probable territory since by connecting all the oil fields of the world by lines it would be hard to find a locality that would not be reasonably near one of these lines. There is no more reason for considering the region between the Oklahoma and Gulf fields as all being favorable for prospecting than for considering all the territory between the Oklahoma and California fields or between the California and Pennsylvania fields in the same way. The oil in the Gulf and California fields occurs under very different conditions from those of the Oklahoma fields. The rocks in the former fields are much younger than those in Oklahoma, and if the productive rocks of Oklahoma are present at all in the Gulf and California fields they are buried under thousands of feet of younger rocks.

When a single field is considered it is evident that the trend of the whole field will be in the same direction as that of the outcrop of the rocks containing the oil and gas. For instance, in the northeastern Oklahoma field the oil and gas is all contained in a thickness of about 1,000 feet of rocks and these rocks outcrop from north to south and dip to the west. It is evident that oil and gas can be found where the local conditions are favorable in a belt to the west of the outcrop in which the oil-bearing rocks lie at a depth of less than 4,000 feet. The development of the field as a whole will therefore be in a north-south belt.

The conditions of deposition also tend to produce trends in oil fields regarded in a broad way. The conditions favorable for accumulation are in the belt of maximum mud deposition, intermediate between the near-shore belt of sand, and the off-shore deposits of limestones. This mud belt will naturally have a more or less definite trend paralleling the shore line at the time the beds were deposited.

The individual pool, in a productive belt, may extend in any direction to that of the field as a whole, in spite of the common idea that all lie in one direction. For example, the northeastern Oklahoma and southeastern Kansas field has a general north-south trend as has been said, but the individual pools may trend in any direction. The Coody's Bluff-Alluwe and the Hogshooter pools extend north and south, the Delaware-Childers pool east and west, the Copan and the Dewey-Bartlesville pools northeast and southwest, the Henryetta-Schulter and Morris pools northwest and southeast, and the main portion of the Glenn pool is almost circular. The individual pools in the Kansas part of the field have their long axes in all directions. The direction of the long axis of a pool depends usually on the structure and in any region the majority of the folds are likely to have their long axes in the same direction, so that it is probable that the majority of the pools will trend the same way. There are, however, almost always exceptions to this rule, and the development of a pool cannot be certainly predicted on the basis of that of other pools in the vicinity unless it is known that the structure is the same.

Oil Seeps and Asphalt Deposits—Among the features that are often cited as indications of oil and gas are the so-called oil seeps which occur in practically all parts of the state. True oil seeps are undoubtedly proof of the presence of oil or asphalt, but such seeps are rare in the Mid-continent fields.

Asphalt seeps are known in the Uvalde region of Texas, and are reported from Coke and Stephens counties. Seeps and deposits of asphalt and very heavy asphaltic oil occur in many places in and around the Arbuckle Mountains in Oklahoma, around the Wichita Mountains and in the region between the two mountain groups. Several small deposits of asphalt have been found in the Trinity sand in southern Oklahoma and in Montague county, Texas. Hard, brittle asphalts are present in the Ouachita Mountain region in Oklahoma.

In considering an oil seep or asphalt deposit as an indication of the presence of considerable bodies of oil underground, a careful study of the geologic conditions must be made.

In regions where there is considerable faulting or intrusions of igneous rock the oil seep may have its origin in deposits of oil which are deeply buried. The faulting or the intrusions may have so broken the rocks as to permit of the escape of a small portion of the oil, forming a seep. Such conditions exist in California, Mexico, South America and in other foreign fields.

In these regions the presence of oil seeps is a valuable aid in prospecting for oil. Seeps of oil and gas have also been of value in locating the salt dome fields in the Gulf Coast region in Texas and Louisiana.

On the other hand, oil seeps in a region of undisturbed rocks are generally of little value as an aid to prospecting. Such seeps generally result from the exposure of an oil-bearing sand by erosion and represent only the remains of what may have been a considerable body of oil. Naturally, these seeps prove the petroliferous nature of the beds in which they occur and may point to the advisability of prospecting in those beds back from the outcrop where the beds are sealed from the surface and where the structural conditions are favorable.

Another factor which must be taken into consideration in determining whether or not an oil seep has its origin in a deeply buried oil reservoir, is the age of the rocks in which the seep occurs.

It is apparent that a seep means that some of the oil is escaping and that, if the escape continues long enough, the supply be depleted.

In the case of rocks as old as the Pennsylvanian and where the folding also is old, it seems evident that any body of oil which had an outlet to the surface through a seep would be exhausted before this time. A deposit in Cretaceous or Early Tertiary rocks, which were folded in late Tertiary or Pleistocene times, might show considerable seepage and still have a great supply in the buried reservoir.

The presence of veins or beds of hard, brittle asphalt, cannot be regarded as favorable indications of oil in the accompanying rocks and are probably the remains of oil bodies from which all the lighter constituents have escaped.

Any surficial occurrence of oil or asphalt is worthy of investigation. The conditions under which they may occur are so variable that generalizations concerning them are difficult to make. However, in most cases the most important oil fields in Cretaceous or Tertiary rocks are accompanied by oil seeps, but seeps are very rare in connection with the fields in the Pennsylvanian rocks. Also, oil seeps in Cretaceous or Tertiary rocks are much more likely to originate in a buried accumulation of oil than are those in the Pennsylvanian or older rocks, most of which are produced by the uncovering of an oil-bearing stratum.

Many reported oil "seeps" are due to other substances than petroleum. In the majority of cases the "seeps" have proved to be merely thin scums of iron oxide on the water. This gives the appearance of a thin layer of kerosene, but is easily distinguished from it. If an attempt is made to skim off the "oil' the scum breaks and separates into angular pieces. If the water is stirred up the crust or scum will be broken up and will settle to the bottom. The behavior of a true oil scum is of course quite different. Further tests which are quite easily made and which establish definitely the identity of the scum are those with acid, preferably hydrochloric. and carbon bisulphide, both of which can be easily obtained at any

drug store. If some of the water with as much of the scum as possible be collected and placed in a bottle or glass and a little hydrochloric acid added a scum due to iron will dissolve and give a brown colored solution. This may be tested still more definitely for iron by adding a little of a solution of potassium sulpho-cyanate to the brown liquid. A brilliant deep red color is produced if iron is present. This red color is a very delicate test for iron and will often show its presence when the brown color of the hydrochloric acid solution is very faint. It should be said that the potassium sulpho-cyanate is very poisonous and care should be taken in using it. A few drops of a strong solution is all that is necessary to make the test. The solution to be tested should not be very strong with the acid. A film of pure oil is not affected by the acid and will give no test with the potassium sulpho-cyanate unless the water with it is strongly charged with iron. On the other hand, if carbonbisulphide is used instead of the acid an iron film or scum is not affected in any way, but any oil present is dissolved in the bisulphide and gives it a dark brown color. The bisulphide and the oil settle to the bottom of the bottle with the colorless water on top. These tests can be made at an expense of a few cents and a few minutes of time and should always be made before any great expense is incurred in the investigation of a supposed oil seep. In nine cases out of ten any scum or film on water (outside of the oil region where the streams are covered with waste oil from the wells) will be of iron and not of petroleum or other oil.

Iron also causes another appearance which is often mistaken for an indication of oil. Some of the iron compounds are black and when wet have a greasy appearance. Irony sands are found in several localities in the State, especially in the Redbeds region, that appear oily when they are wet. The test by the hydrochloric acid is sufficient to show that this appearance is due to iron since a weak solution of the acid will dissolve the black coloration and leave ordinary sand while the solution becomes brown. The further test with the potassium sulpho-cyanate can be made if desired, but is really not necessary.

In considering a seep it should be borne in mind that crude oil is usually a thick liquid and dark in color so that the thin oily films due to iron do not at all resemble a covering of crude oil, although they do somewhat resemble one of kerosene or coal oil. The latter, however, is a refined product of the crude oil that is never found as such in nature. A few seeps of a dark substance having the appearance of crude oil have been reported from localities in western Oklahoma and some samples have been examined. In general these "seeps" are found in the bottoms of canyons and can usually be attributed to the decay of vegetable matter which is washed down into the canyons at times of heavy rains. The amount of the oily

substance is very small and the seeps occur only in times of wet weather.

The Use of Instruments—So far as is known there is no instrument that is of the least service in locating deposits of oil and gas except the ordinary surveying instruments which are used in determining the structure of the rocks. There is no substance known that is either repelled or attracted by oil or gas. In spite of these facts there are many communities in the region that have paid "oil witches" considerable sums of money to have them locate drilling sites by the means of some sort of instrument. In a certain case to the writers' knowledge one of these witches received $25 each for locating three wells. One of the wells was located on an outcrop of the granite of the Arbuckle Mountains and the other two were in places where the granite was probably not over 100 feet beneath the surface. In another community in the western part of Oklahoma a negro with a considerable amount of paraphernalia was successful in obtaining small sums of money from several parties for locating wells. These wells were located on sand hills where the Redbeds would be encountered at a depth of probably less than 100 feet and where these beds are at least 1,500 feet thick. This operator is reported to have told some of the men who accompanied him that at one place they were walking over the largest lake (or pool) of pure gasoline that the world has ever known. Since the world has never known, very little, if any gasoline to be found in a pure state in the rocks, the lake need not have been very large to have fulfilled the description.

A little consideration will make it plain that if a man had an instrument or substance that would locate definitely deposits of oil and gas it would not be necessary for him to do locating at the rates charged by such men. The possession of such an instrument would enable one man to locate sufficient wells to flood the market and to destroy the petroleum industry in a year or two. If such a substance or instrument existed it would be to the advantage of large oil companies to pay the owner enormous sums of money to refrain from locating more wells. It is certainly safe to say that men claiming such powers are either conscious or unconscious fakers.

Use of Geology—The application of geology to the location of oil and gas fields is of comparatively recent origin. The first use of the anticlinal theory as a means of locating new territory dates back less than fifty years, and the common use of geology by oil operators has come about in the last 10 to 15 years.

Necessarily, in a science so young as this which deals with conditions so indefinite, many mistakes have been made and there is still much to learn. It is now generally recognized, however, that geology is of great aid in prospecting and practically all the larger producing companies have geological departments as a constituent

part of their organization. Many of the smaller companies and the individual operators and promoters use the services of consulting geologists.

Any attempt to describe the methods of geological exploration is difficult since the conditions differ so widely in the various parts of the Mid-continent region that methods giving excellent results in one locality cannot be used in another. However, the methods of geologic work can be roughly classified into reconnaissance and detail methods. The two grade into each other and a third type of geologic exploration, the detailed reconnaissance may be recognized.

Reconnaissance Methods—The fundamental factor upon which any geologic survey for oil and gas must be based is a thorough knowledge of the general geology of the region. The character of the rocks, and their succession must be known before it can be decided whether the region is, in general, favorable for oil and gas. In a virgin territory, therefore, the first thing necessary is a study of the geology in a broad way. This study should decide whether or not the rocks within reach of the drill are such as to make the accumulation of oil and gas probable.

The area here considered as the Mid-continent field has been fairly well known geologically for a number of years and the general geologic features have been mapped and described so that a study of the literature makes any general geologic surveying unnecessary.

Certain areas, such as the greater parts of the Arbuckle, Wichita, Ozark, Ouachita, and Llano-Burnet mountains and parts of trans-Pecos Texas, can be certainly classed as non-productive territory from a knowledge of work already done the results of which have been published. Other areas can be classed as possibly productive but with the chances very small, and other areas can be said to have good chances for production if local conditions are favorable.

After deciding whether the general conditions are favorable, the geologist must determine in what localities the local conditions are most favorable or whether the conditions on a given tract submitted for examination are such as to justify leasing and drilling. Since the structure of the surface beds is the only one of the factors influencing accumulation which can be determined in advance of drilling, the investigation in "wild cat" territory resolves itself into a determination of the structure of the area.

The simplest method of determining the structure, is that of reading the dips of the exposed beds and recording them on the map by means of dip and strike symbols properly located.

Dips are usually read by means of a clinometer which consists of a half-circle, graduated into degrees, with a pointer pivoted in the center of the circle and hanging over the graduated scale. The

base of the instrument is straight and parallel to the diameter determining the half-circle, so that when the instrument is set on an inclined surface, the angle of inclination, or dip, from the horizontal may be read directly from the position of the pointer on the graduated scale. The clinometer is generally combined with a compass as in the instrument shown in fig. 11. In this instrument the arm which acts as the base may be turned into a vertical position, and is

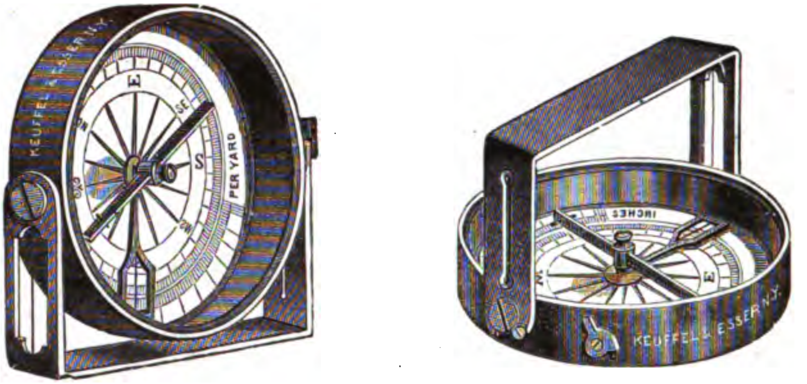

Fig. 11.—Clinometer compass with open sight alidade attachment.
a. with alidade lowered for use as clinometer.
b. with alidade raised for use as sight compass.

slotted so that it may be used as an open-sight alidade. The needle may be clamped so that sights may be taken on objects and their direction from the observer read directly from the compass.

A different type of clinometer is the Brunton compass (fig. 12.) This is provided with a spirit level which is on one end of an arm which is pivoted at the center of the compass circle. The other ends bears a vernier scale which reads against the graduated half-circle. When the instrument is opened the side of the box and the lid make a straight-edge which may be placed on the bed whose dip is to be determined (or may be sighted across when held parallel to the bed). The vernier-spiritlevel arm is then adjusted (by means of an arm at the back of the instrument) so that the bubble shows level, when the angle of dip may be read from the position of the zero of the vernier scale on the graduated circle. The Brunton compass may also be used to take sights to determine direction and to determine angles of elevation and depression. When the zero of the vernier scale is set to coincide with the zero of the graduated circle, the Brunton may be used as a hand-level.

It is apparent that the method of reading dips by clinometer is applicable only to areas in which the dip is sufficiently great to overcome the natural inaccuracies of the instrument. The surface of a bed is never a perfect plane and the surface slope due to the minor irregularities, in a short exposure may be greater than the dip of

the bed, if this be low, and readings with the contact clinometer may give totally erroneous ideas as to the direction and amount of dip. Where the exposures are several feet long and the rocks well-bedded the Brunton compass may be used, by sighting across it when it is held parallel to the beds, even if the dips are quite low. In general, a contact clinometer should not be depended upon when the dips are less than 2 or 3 degrees nor the Brunton when the dips are less than 1 degree.

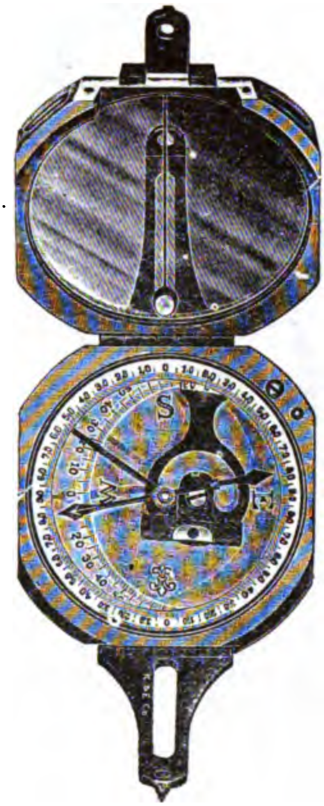

Fig. 12.—Brunton compass.

A situation in which the dip-reading method may be used is in regions where the outcrops are few and short and where the individual beds cannot be correlated from one outcrop to another. With these conditions, even if the dip is very low, the only method of determining the structure at the surface is to use the Brunton compass to measure the apparent dips, and to plot their locations carefully. The results cannot be regarded as strictly accurate but still will often show the presence of abnormal structural conditions and enable one to locate the axis or folds within a reasonable limit of error. The amount of closure of a favorable structure cannot be determined by this method, but in some cases, an estimate can be made from the amount of dip shown. The accuracy of any work of this sort is of course, almost entirely dependent upon the nature of the beds and the number and character of the exposures.

In most of the probably productive areas in the Mid-continent field the rocks are well-bedded, and the outcrops fairly numerous The individual beds may be traced for considerable distances. The dips are low, generally less than 1 degree, and in most places, not over 20 to 50 feet to the mile. Under these conditions the method of determining structure by reading dips is not practicable and methods which involve the determination of the relative elevations of different points on the same bed of rock must be used.

The instruments most used for reconnaissance work in areas of this type are the aneroid barometer and the hand-level.

The use of the aneroid barometer depends on the fact that the air pressure diminishes with elevation. The instrument in general appearance resembles a large watch, with a single long hand or

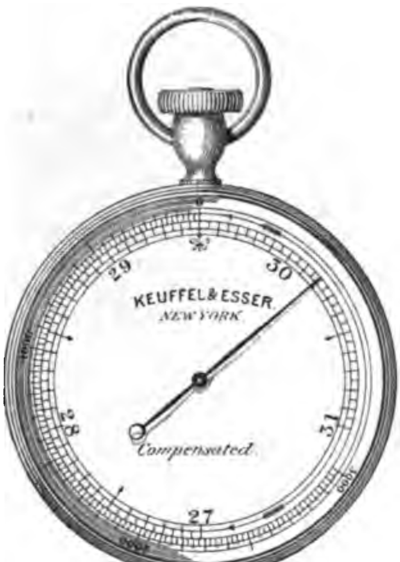

Fig. 13.—Aneroid-barometer (K. & E.)

pointer. A diaphragm parallel to the face divides the body of the instrument into two compartments. The compartment in front has the air partially exhausted and is sealed and the back compartment is open to the air. As the air pressure varies in the back compartment it presses with a greater or less force on the diaphragm and since the pressure on the front of the diaphragm is constant, causes a slight movement forward or backward as the pressure increases or diminishes. This movement is transmitted to the pointer by a magnifying mechanism. The scale on the face of the aneroid reads in feet of elevation and also shows the corresponding readings for the height of the mercuric barometer in inches. The barometer, naturally, registers the difference in atmospheric pressure due to varying weather conditions and the change in readings in a short time due to this cause may be much greater than that due to difference in elevation. For instance, on a "squally" day, it is not an uncommon experience to find that the barometer gives a lower reading at the top of a hill than it did at the foot, or vice versa. Then, too, the barometer is a very delicate instrument and is very likely to get out of adjustment. The position in which it is held also affects the readings of most barometers. The readings should also be corrected for temperature unless the instrument is compensated.

In spite of all these drawbacks the aneroid barometer may be used to advantage in localities where the distance between observation points is not too great or where the barometer readings can be checked at frequent intervals. In those parts of Kansas or Oklahoma where there are roads on most of the section lines a fairly accurate aneroid net of elevations may be made. For example, if it is desired to work a given township in which the elevation of, say, the southwest corner is known the elevations along the south township line may be determined by driving east along the line, reading on each section corner, then north a mile and back west to the township line and south a mile to the starting point where the barometer may be checked. The time of each reading should be noted and any change in the barometer should be distributed over the traverse in proportion to the time interval for each read-

ing. By proceeding in a similar manner the elevations of all the section corners may be determined in a comparatively short time. Where all the section lines are open as roads and if an automobile can be used, the elevations thus established should be correct within a small limit of error, say 5 or 10 feet.

The geology can then be sketched in by mapping in the outcrops by pace traverse or compass sights on objects whose location has been determined. Readings may be taken on outcrops wherever desired and the time noted. The barometer should be checked by a reading on a section corner at frequent intervals and the variation be distributed over the readings on the outcrops.

By using a good barometer and frequently checking it on points of known elevation a geologic map can be made which will be very nearly as accurate as one made by plane-table survey but when properly done the work is slow and has no advantage over the plane-table survey except that it may be done by one man, which is an important point in case a plane-table outfit and instrument man are not available.

It should be said that aneroid barometers are made in a great number of styles and in sizes of from 2 inches to 5 or 8 inches in diameter. In price they vary from a few dollars to a hundred dollars or more. In general the cheap instruments are unreliable and unsatisfactory. A good type for rapid reconnaissance work is one with a 3-inch dial, with the scale rotated by a ratchet and with a small lens for reading the elevations. For the more detailed work the larger types are preferable since they can be read more accurately. They are heavier to carry but the increased accuracy of the work more than compensates for this drawback. For work in the Mid-continent fields a barometer which reads to 3,000 feet is preferable to one reading to higher elevations on account of the greater accuracy with which they can be read.

For determining relative elevations of two points within sight of each other the hand-level is used. The small hand-levels are of two types, the square-barrel (fig. 14) and the round-barrel, or Locke level, (fig. 15). Both depend on the reflection of the bubble

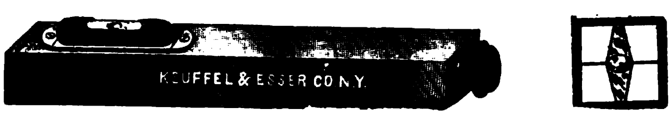

Fig. 14.—Square-barrel hand-level.
a. View of level.
b. Field vision.

of a spirit level, which is fastened on top of the instrument, across the field of vision. A cross-hair bisects the reflection of the bubble when the instrument is level. In the round-barrel one-half

of the field is occupied by the reflection of the spirit level. In the square-barrel level the field of observation lies on both sides of the reflection of the bubble. The choice between the two types is largely a matter of personal preference. They are equally reliable and both are easily adjusted.

For somewhat more accurate determinations of relative elevations of points within sight of each other, the stadia hand-level (fig. 16) is very valuable since, on account of its greater length, it is much more accurate than the hand-levels, and is provided with a magnifying lens which enables the observer to pick out objects at a distance, much more readily and accurately than is possible with the small levels. It can also be depended upon for

Fig. 15.—Round-barrel or Locke level.

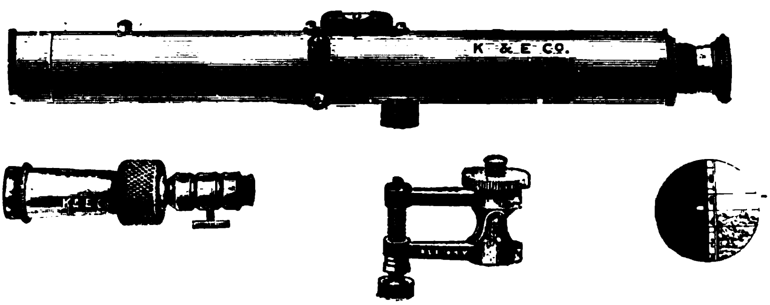

Fig. 16.

a. Stadia hand-level.
b. Attachment for Jacob's staff.
c. Leveling attachment.
d. Field of vision.

accurate readings at much greater distance than can the small levels. The principal objection to its use is that it is difficult to hold it steadily enough in the hands to bring the bubble to rest and it must be used with Jacob's staff or rested upon some solid object while the observation is being made. This feature makes it unavailable for use in the rapid measurement of the thickness of a section of rocks or the interval between beds. For this purpose the small levels are sufficiently accurate and are much more rapid than the stadia level. The stadia feature is of value in rapid reconnaissance, since by noting the portion of the interval between the cross-hairs covered by objects whose approximate height is known, such as houses, fence posts, windmills, etc., a fairly correct estimate of distances may be made, or if the distance is known the

difference in elevation between the observer and the point observed may be estimated.

In determining relative elevations of points on a bed of rock it should be constantly kept in mind that the relative elevations of only two points or of several points in a straight line do not determine the dip of a bed. For example, if the observer be at the level of a given bed and observes that a point on the same bed to the southeast is a lower level, it may mean that the bed is dipping to the southeast or it may indicate any of the following conditions:

(a) A due south dip.
(b) A due east dip.
(c) A southwest dip with the south component greater than the west.
(d) A northeast dip with the east component greater than the north.

To determine the true direction of dip it is necessary to consider the relative elevations on at least three points, not in a straight line.

In any sort of reconnaissance work one of the prime requisites is the keeping of one's self located on the map. In Kansas and Oklahoma, this presents little difficulty since all the land is divided in the township and range system and nearly all the section lines are "opened" for roads. In most of Texas, however, the land surveys are very irregular, the land lines may run in any direction and the present property lines do not necessarily coincide with the original survey lines which are shown on the only base maps available. The roads do not follow the land lines and, generally, reliable road maps are not available. A considerable area in north-central Texas is covered by topographic maps of the United States Geological Survey but most of these are merely reconnaissance maps and are so generalized and the culture is so out of date that they are of little assistance.

For reconnaissance work in Texas about the only method of keeping one's location is to secure the land map of the county, start from a known point and determine distance traveled by means of automobile speedometer or buggy-wheel revolutions. The tally register is of great assistance in counting paces or revolutions. Directions may be determined by the Brunton compass with considerable accuracy. Locations should be checked frequently by finding from the farmers or ranchmen the location of the survey lines and corners.

A somewhat more accurate method of determining directions than by using the Brunton compass is to use the open-sight alidade (fig. 17) to locate objects by means of triangulation.

The open-sight alidade is used with a small plane-table. It is often used with the aneroid barometer in preparing topographic

Fig. 17.—Open-sight alidade (B. & L.)

maps of small areas. A considerable number of intersections are made with the alidade, and the elevations determined with the barometer.

Detailed Methods—Detailed geologic mapping consists of making an accurate map of the territory investigated, on which are shown the outcrops of the important formations and the elevation of the outcrops at a large number of points. The land survey lines, the property lines, the drainage, roads and houses are generally shown. The instruments generally used for detailed mapping are the telescopic alidade and plane-table. The transit may be used but where so many things are to be shown on the map the taking and transcribing of so many notes becomes a serious proposition. The plane-table permits the map to be made in the field and reduces the note-taking to a minimum. The details of plane-table surveying methods cannot be given here but may be found in any good text on Surveying.

Fig. 18.—Miniature (Gale) alidade (B. & L.)

The type of alidade most generally used in geologic mapping is a small, portable instrument, built on a design by H. S. Gale of the United States Geological Survey and usually known as the

Gale alidade. This instrument as manufactured by the Bausch & Lomb Optical Company is called the miniature alidade (fig. 18). This instrument has the advantage of extreme portability, being carried in a sling case about 4 inches square and 12 inches long.

A larger type of instrument with a high standard is known as the Frontier (B. & L.) alidade (fig. 19.) A third type is about

Fig 19.—Frontier (high-standard) alidade (B. & L.)

intermediate in size between the two just mentioned but is built on the lines of the Frontier model.

As has been said, the Miniature or low-standard alidade has been the most used in the Mid-continent field. However, it is the writer's experience that most instrument men prefer the larger types when they become accustomed to them. They are more accurate than the smaller types, and have better magnification so that longer shots may be taken. They are, of course, not so easily carried as the small instruments and their cost is greater. They also give an inverted image while the small type gives a direct image. These disadvantages are more than offset by the increased accuracy and the speed of the work. The small type is to be preferred only in regions in which the portability is a very important feature.

The size of the plane-table top (planchette) is governed by the scale on which the mapping is done. The two sizes most used in the Mid-continent fields are 15 inches and 24 inches square. The tripod should be substantial enough to resist vibration from the wind, but light enough to be carried easily. The tripod-head most

used is the Johnson head (fig. 20) which permits orientation and the quick and accurate leveling of the planchette, and which clamps firmly in position when adjusted.

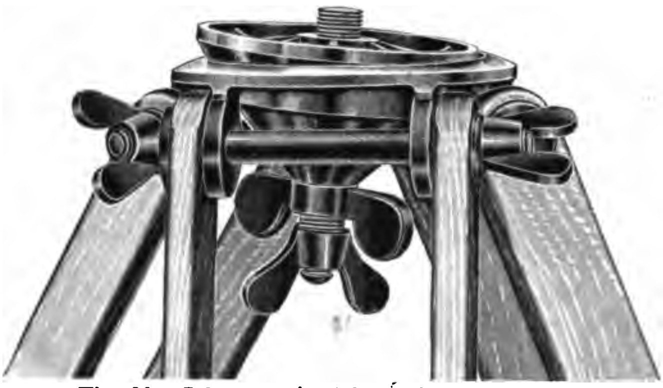

Fig. 20.—Johnson tripod head for plane table.

Detailed Reconnaissance—One of the larger producing companies in Oklahoma has used a method which may be called detailed reconnaissance. Elevations are established on section corners, bridges, road intersections, gate posts and other similar features by traverses with alidade or transit. The geology is then mapped by the geologist who sketches the outcrops and determines elevations on outcrops by means of the aneroid barometer, "tying in" to the established points at frequent intervals for location and elevation. The term detailed reconnaissance might also be applied to the method described under the discussion of the aneroid barometer.

Mapping the Structure—Structure is shown on maps in two ways: by dip and strike symbols and by contours.

Dip and strike symbols are plotted on the map in the localities where dip readings were taken. The length of the outcrop on which the dip is taken may be indicated approximately by the length of the dip line. The rate of dip is usually indicated by writing the number of degrees of dip, or the number of feet of dip per mile beside the dip and strike symbol.

A portion of a map showing dip and strike symbols is shown in fig. 21.

This map represents an area in which outcrops are few and short and correlation impossible. Most of the outcrops are in road-cuts and since only one component can be determined the dips appear parallel to the roads in most places. The map is interpreted as showing a southeast dip, the small reverse dips being due to cross bedding or slump.

In contouring, a prominent and persistent bed is usually chosen as the datum bed and the elevation above sea level of the

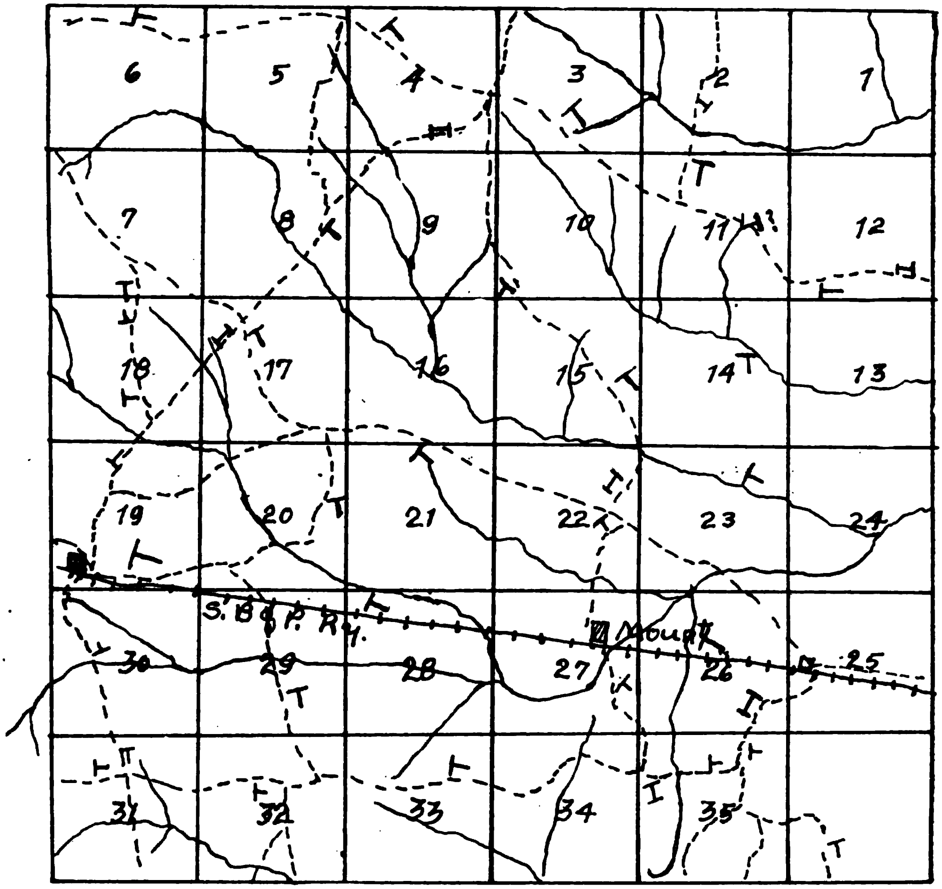

Fig. 21.—Map of small area showing use of dip and strike symbols.

points on its outcrop are placed on the map. Contour lines may then be drawn through the points of equal elevation. It is evident that one bed can be used through only a narrow belt since it will quickly dip beneath the surface. In this case, the interval between the datum bed and a higher one is determined and the amount of the interval subtracted from the elevations as determined on the higher bed. When working on beds lower in the section than the datum bed, the interval must be added to the elevations. A map prepared for contouring, then, will show the actual elevations on the datum bed where it outcrops, and on higher or lower beds will show the elevation, not of the beds themselves, but of the datum bed at those points, presuming that the intervals remain constant in the direction of the dip. The intervals along the strike should be determined at several places and allowance

for thickening or thinning of the beds lying between the beds being mapped and the datum bed be made.

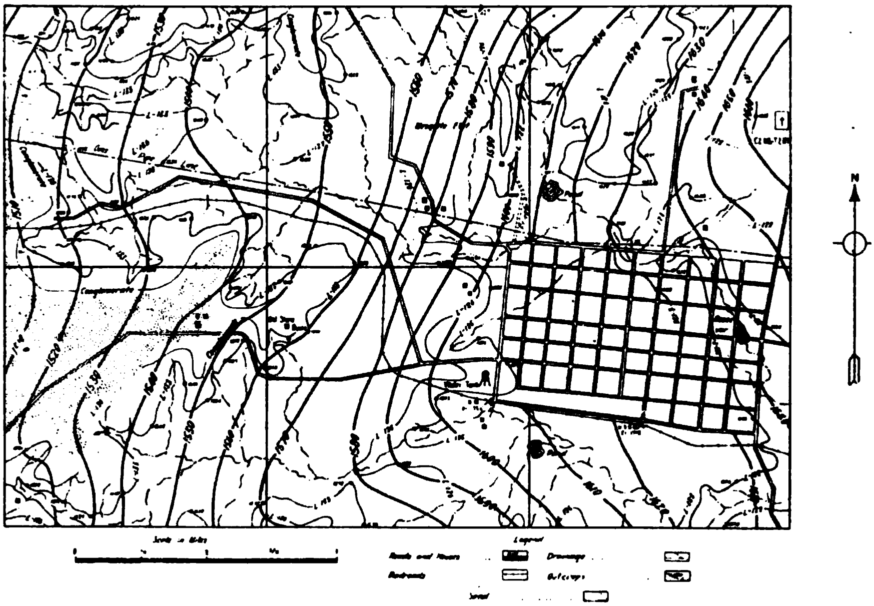

Fig. 22.—Portion of a completed detail map.

Reports—The final geologic map of an area is usually accompanied by a brief report giving a resume of the principal stratigraphic and structural features, a discussion of the probable presence of productive sands and their depth and thickness. Any drilling which has been done in the vicinity should be carefully noted in this connection. Such features as leasing conditions, transportation facilities, water and fuel supply should receive careful attention since they are of great importance in the development of a region.

The exact nature and scope of the report will, of course, depend almost entirely on the nature of the investigation and the desires of the parties for whom the work is done.

Locating of Wells—After the more favorable localities of an area have been selected by means of a determination of the structure, the next question which arises is that of the exact location of the well. This will depend somewhat on the nature of the structure found. If the structure is an anticline whose sides have an equal or nearly equal dip the first well should normally be located on or near the crest or line where the dip changes. This is especially true in an undeveloped territory as it would be much better to strike a good flow of gas than to take chances of going too far down the slope of the anticline and strike the oil sand below the oil belt. In a

broad, low anticline the well may be located at a somewhat greater distance from the crest than on a narrow, sharp one. Where the anticline is asymmetric, that is where one side dips much more

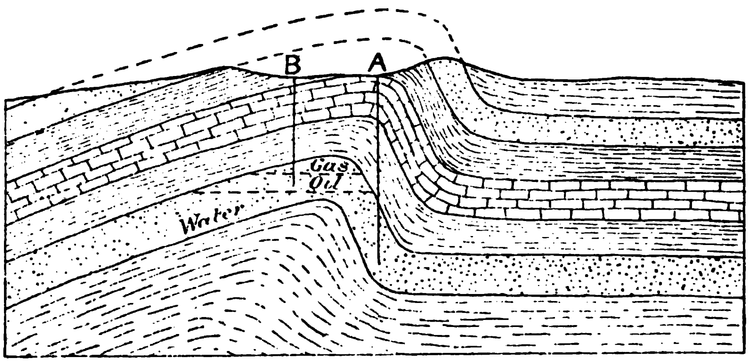

Fig. 23.—Diagram illustrating the accumulation of oil and gas in an asymmetric anticline.

steeply than the other, the well should be located down the slope of the gentler side. The reason for this is apparent from the accompanying diagram (fig. 23). It is readily seen that, in an anticline of this sort, the crest moves down the dip of the gentler side with increasing depth. Consequently a well, *A*, started on the crest at the surface would be a considerable distance down the slope of the steeper side by the time it had reached the depth of the oil-bearing sand, and that to encounter the oil-bearing sand at the crest of the fold in it, the well would have to be started down the slope on the gentler side of the anticline, say at *B*. It is also apparent that the width of the oil belt is much greater on this side of the anticline than on the other. The distance from the crest at which the well should be started depends on the steepness of the slope of the sides and the depth to the supposedly oil-bearing sand. These factors, of course, must be worked out for each fold individually.

If the structure is a terrace or arrested anticline instead of a true anticline the location of the well should be somewhere near the top of the steep slope, i. e., near the line of change of dip. The exact location should be determined by one acquainted with the structure and the section to be encountered in drilling, since there are several factors which affect the location which can be determined only by an examination of the vicinity and a knowledge of the general geology.

Depth to Which Test Wells Should Be Drilled—After a well has been located, a consideration of the depth to which it should be drilled before it should be abandoned as dry is

an important consideration. In some cases this can not be determined. Drilling should not stop until the horizon of the lowermost sand which is liable to be encountered is reached. For example, in the great oil region of Oklahoma, the northeastern part of the State, the oil and gas-bearing rocks outcrop to the east of the development and dip under the surface to the west. From a knowledge of the rate of dip and the distance of a locality to the west of the outcrop of the sands, or from a place where their depth is known, the depths of the possibly producing sands of the locality in question can be prophesied with a fair degree of certainty. The dip through the oil and gas region mentioned has been found to be quite uniformly 30 feet to the mile. Supposing then that a well is started 20 miles west of a proven pool, the sands in the new well will be encountered at depths approximately 600 feet greater in the new well than in the pool to the east, if the mouths of the wells are at about the same level. A sand which lies at 500 feet in the old pool should be expected at about 1,100 feet and a sand found at 1,200 feet in the old pool should be found at about 1,800 feet in the new location. Any difference in the elevations of the wells should be added to the difference in the depths of the sands in the two localities as determined by the dip, if the new well is higher than the old, and subtracted if it is lower. There is always a possibility that the sands of the developed pool do not extend under the new location and also that sands will be found in the new location which were not present in the old. The principal producing sands of the northeastern Oklahoma fields, for instance, the Bartlesville and Cleveland sands, are known to be continuous over large areas and can be depended upon with some degree of certainty. Drilling in any locality should be carried to a sufficient depth to reach the lowest productive sand, unless this depth is so great as to be impracticable. Even if production is found in the higher sands the deeper sands should be tried out in some wells at least.

The advantage of knowing the position of the productive sands and the depth at which they are to be expected is shown by two examples that recently came to the writer's knowledge. In one case a well was drilled a considerable distance farther east than any work previously done by those connected with the undertaking. The hole was carried to a depth of about 2,000 feet in search of the Bartlesville sand, when, in fact, this sand was passed through at a depth of about 700 or 800 feet and about one-half of the hole was in the Mississippi lime and the rocks beneath it. In another case a well was started even lower than the one just mentioned, so that it was not over 100 feet to the Mississippi lime. The hole was drilled to a considerable depth in the hope of striking the sandstones which are productive farther to the northwest.

What is probably the lowest of these productive sands, outcrops as a range of hills a few miles to the west of the location of the well. In either of these cases even a general knowledge of the geology of the region would have saved the parties drilling the wells considerable sums of money.

Value of Wild-Catting—In some places it is practically impossible to get much aid from geology in determining whether or not a certain locality, in a region which is in general an oil and gas region, is particularly favorable for development. Some of these cases are where the surface rocks are so soft that they weather down without giving good exposures; in places where the accumulation is in lenses of sand which are included in shale without giving any surface indications (fig. 9); and in places where the accumulation is largely controlled by variations in the coarseness of the sand. The possibility that these conditions may occur gives considerable justification for what may be termed rank wild-catting, although the chances for finding production are much less than in localities where the structure can be made out and the more probable places selected. Even in such places a knowledge of the general geology of the region should be of great assistance to the prospector in deciding whether or not he wishes to take the chance of drilling in the unproved territory.

In drilling such wells careful records and sets of samples of cuttings should be kept since these are of great value in determining the geologic conditions and may show the advisability of further prospecting.

DRILLING.

Two methods of drilling are used in the Mid-continent fields: the standard or cable tool system and the rotary system. In some cases, both systems are used in one well and this practice may be called a third—the combination system.

Standard or Cable Tool System.

Drilling by this system is accomplished by alternately raising and lowering a heavy weight of tools so that they strike blows upon the formation to be penetrated and pulverize it. The pulverized material is removed in water.

The necessary outfit consists of a boiler, engine, derrick or rig, crown block, tools and accessories, sand line and reel, and drilling cable.

The boilers and engines used vary considerably in different fields. The boilers used in the Mid-continent fields are practically all horizontal tube boilers of the locomotive type. Both boilers and engines are of portable size, and are moved from one location to another as the wells are finished.

The rig consists of the derrick proper, and the necessary foundations, wheels, the samson post, walking beam, and pitman. A side elevation of a standard rig is shown in fig. 24.

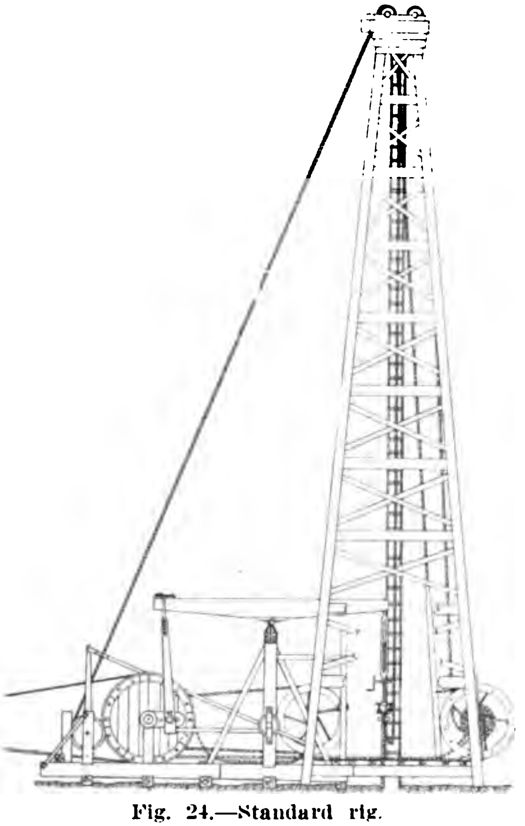

Fig. 24.—Standard rig.

The derrick generally used in the Mid-continent field is 84 feet high.

The tools in common use consist of the rope socket, drilling jars, drill stem, and bit, which are all joined together by box and pin screws. Together the tools are known as a "string." The rope socket (fig. 25) has an opening from the top to the side. The opening at the top is cylindrical and of the size of the rope or cable to be used. The one on the side is elliptical and somewhat larger. To attach the socket, the end of the rope is passed into the cylindrical opening and on out of the larger elliptical opening. Then the cable is unraveled for a distance of several inches from the end and more material is skillfully plaited between the strands of the cable thus increasing the diameter of the end so that it is firmly held in the opening through the rope socket.

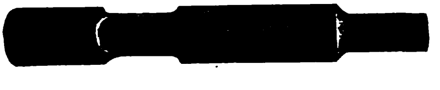

Fig. 25.—Rope socket.

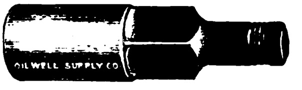

Fig. 26.—Rope socket for wire cable.

Devices other than the one just described are used but they are all similar. A socket for wire cable is shown in fig. 26.

The jars (fig. 28) are interlocking links or reins. In drilling they slip down over each other a short distance as the blow is delivered and, as the tools are lifted, the upper strikes the lower with a sharp blow which will loosen the tools from the bottom of the

hole. The jars are very valuable in preventing the breaking of the cable by the bit becoming fast in the rock which is being penetrated.


Fig 27. Stem.


Fig 28. Jars.


Fig 29. Bit.

The stem (fig. 27) is simply a cylindrical bar which gives weight to the string.

The bit (fig. 29) is a very heavy piece of steel with the bottom end shaped and sharpened to make it an effective cutting tool. Channels on the side form a passage upward for the cut-up rock material which is churned up with the water which is kept in the hole while drilling is going on.

An additional tool which is sometimes used is the sinker bar which is similar to the stem but only about one-third as long. When used it is usually placed between the rope socket and the jars.

Although not a part of the ordinary "string" of tools, the under-reamer (fig. 30) is much used in the Mid-continent fields, and may be used as a part of a "string." It consists of a section similar to a portion of drill stem but hollow for part of its length and containing a spring which opens a pair of "knives" or lugs with which the instrument is provided. These are closed when the reamer is passed through the casing but open below it. They cut away the walls of the hole making it of slightly larger diameter than that of the bit so that the casing may be carried to greater depth.

The pulverized material is removed by a bailer (fig. 31) which is a shallow cylinder with a valve at the bottom. The bailer is lowered into the hole, after the string of tools is removed, and is churned so that the pulverized rock is mixed up with the water in the hole, and the mixture is forced up into the bailer through the valve. When the bailer is lifted the valve closes and the filled boiler is elevated to the surface. It is emptied by up-ending it or by resting the bottom projection of the valve on a solid object, such as a board, which opens the valve and lets the contents of the bailer escape. The bailer is handled by means of a light cable, the sand line, which is wound on a reel known as the sand reel.

Accidents such as the breaking of the drilling cable or the sand line, or the collapse of the walls of the hole or of the casing are common in drilling and many varieties of fishing tools are used to recover the string of tools or the bailer when they are lost

Fig. 30. — Under-reamer.

in the hole. These tools are often made especially for the situation in which the tools stand in the hole but certain standard types are used in almost every fishing operation. For removing the string of tools, different forms of sockets which slip down over the rope socket of the lost string and take a firm hold by means of slips or a friction hold are used. The jar knocker or bumper (fig. 32), is used to loosen the tools when they have become caught under the casing. The spud (fig. 33) is used to loosen the material around the tools when they are caught in a cave in. The swedge (fig. 34) is forced through casing which has collapsed to restore it to its original diameter and is also passed through new strings of casing to insure that they are of the proper diameter to permit the free passage of the bit.

Fig. 31. Bailer.

Fig. 32 Jar knocker or bumper.

Fig. 33. Spud.

Other accessory tools are the casing-cutter (fig. 35) and casing-perforator (fig. 36.) The casing-cutter is lowered into the casing on a string of tubing to the point where the casing is to be cut. Then a wedge is forced down into the cutter body which forces the knives out against the casing which is cut by rotating the tubing with the cutter. The perforator has perforating points which are held back from the casing until the proper point is reached when they are released by a spring arrangement. The casing can then be perforated by raising and lowering the perforator.

The rope spear (fig. 37) is used to grapple for cable or sand line which has been lost in the hole.

All the tools and accessories described above are made in various sizes to fit the different sizes of casing used in drilling. Where drilling is carried to considerable depths and several sizes of casing

Fig. 34. Swedge.

Fig. 36. Casing perforator.

are used, it is necessary to have four or five complete strings of drilling tools and sets of accessory tools.

In drilling, power is communicated to the band wheel by a belt from the engine. The bull wheels, on which the drilling cable is coiled are driven by a rope pull from a pulley on the band wheel shaft. When drilling is under way, the operation may be described as follows:

The tools are suspended over the hole by the cable which passes upward over a pulley in the crown block and down to the bull-wheels. The bull-wheels are disconnected from the drive by throwing off the rope. A heavy brake-band passes over one of the bull-wheels, and is fastened to the floor of the derrick behind the wheels and to a lever which is fastened to the floor in front of the wheel. On releasing this lever, the bull-wheels are revolved by the weight of the tools which fall down the hole very rapidly. When they have reached the proper position for drilling, the brake-band is tightened by means of the lever which is chained down to the floor. Then the pitman of the walking-beam is fastened on the wrist-pin of the band-wheel, the cable is secured in the clamp of the temper-screw, a few feet of slack cable are run off from the bull-wheels and the engine started. Each revolution of the band-wheel raises and lowers the tools in the hole, and the bit striking the rock at the bottom, cuts it away. The bit is kept hitting on the bottom by letting down the temper screw. The tools are rotated by the driller turning the cable by means of a short lever. After the temper-screw is let out to its limit, the engine is stopped, the slack taken up by turning the bull-wheels so that the weight of the tools is on the crown block, the brake tightened, the rope-drive thrown on, the temper-screw clamp released, the pitman taken off the wrist-pin and set down on the floor, which throws the inner end of the walking-beam upward and out of the way, the temper-screw is hooked back out of the way. Then the engine is started and the tools elevated from the hole. After they have cleared the casing they are hooked back and out of the way. The bailer is lowered to the bottom of the hole and "churned" on the sand-line in order to fill it completely with the water and cuttings and is

Fig. 35. Casing cutter.

Fig. 37 Rope spear

then removed and emptied. The bailer is run often enough to clear the cuttings from the bottom of the hole and then some water is poured down the hole and the tools run down as before.

Barring accidents and the running of new strings of casing, these operations are repeated monotonously until the well is to the required depth.

It is frequently necessary to remove the bit from the stem and replace it by one which has been freshly dressed or sharpened. The bit is loosened by powerful wrenches, operated by a lever on the derrick floor, and can then be removed by hand and the new bit put on while the hole is being baled. The joint is tightened by the big wrenches before the tools are lowered.

Portable Oufits — For drilling to moderate depths, say to 1,500 feet or less, portable drilling rigs mounted on wheels are used extensively. The method of drilling does not differ materially from that used with the Standard rig. A portable drilling outfit is shown in fig. 38. which shows practically all the details. These outfits are commonly known as "Star" rigs in the Kansas and Oklahoma fields.

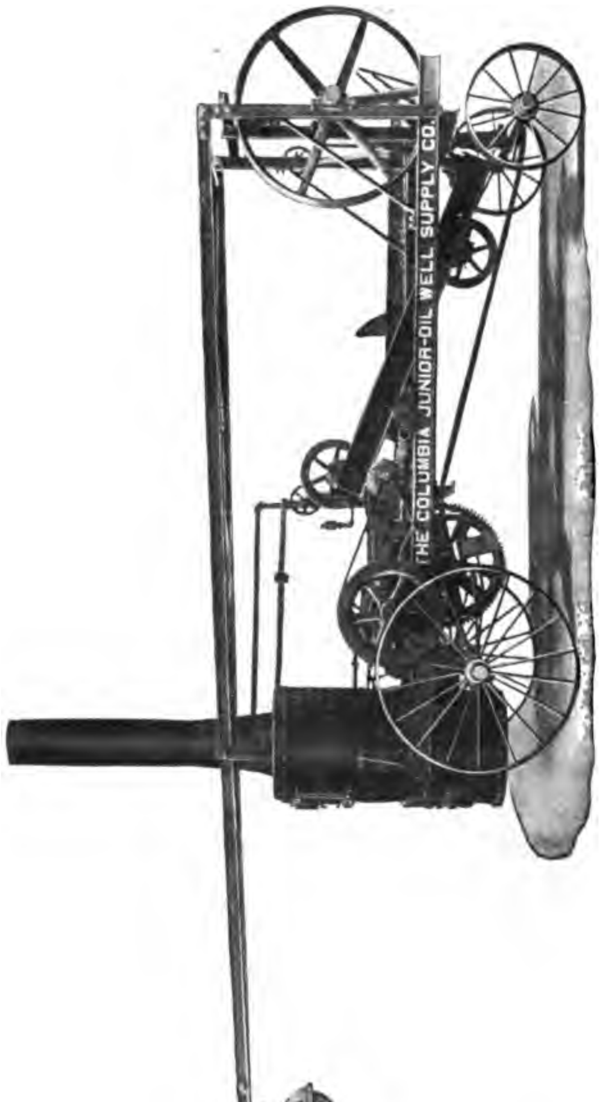

Fig. 38.—Portable drilling rig.

Casing—Casing of several different sizes is used in drilling by the cable-tool system. Drilling can not be carried on successfully with much water in the hole, and, in addition, there is danger of forcing back any oil in the strata penetrated if the hole is full of water. Therefore it is necessary to case off the water sands as they are penetrated. Also, in drilling in very soft formations there is constant danger of the walls of the hole caving, and, to prevent this, the casing must follow the drill closely.

The number of strings of casing used in a well depends upon the depth, the number of water horizons and the nature of the formations. A well deeper than 2,000 feet may use several strings of casing. The conductor may be 15 or 16 inches in diameter, the next string is usually 12½ inches, the next 10 inches; the next 8¼ inches; the next 6⅝ inches; and the next 5⅜ inches. In some wells, a 4-inch casing is used.

In most cases, the outer strings of casing are pulled after the well is completed and may be used again. If the well is a failure, all the casing may be pulled. Very often the casing becomes "frozen"; *i. e.*, the material outside it settles so tightly that the whole string of casing cannot be moved. In this condition the casing may be cut by the casing-cutter or shot in two by a small charge of nitroglycerine and the upper portion of it recovered.

The casing is handled by means of a cable passing over a pulley in the crown block in the same way as the tool cable or the sand line. The casing is supported in the hole by means of a clamp which is fastened under the collar of the casing. A clamp is shown in fig. 39. Another form of clamp has two bails or handles and is used in elevating or lowering the casing. This form of clamp is known as an elevator.

Fig. 39.—Casing clamp.

Packing—The shutting off of water is a very important feature of drilling by the cable-tool system. To render the joint between the casing and the surrounding rock water-tight, packers are used. The original packers were leather bags filled with flax-seed which were packed around the casing just above the water sand. The swelling of the seed forms a water-tight joint. Patent packers are used which generally depend on the expansion of rubber cylinders in a similar way. The casing may be cemented into the rock, if it is not desired to pull the casing later.

Hydraulic Rotary System.

In very soft and unconsolidated rocks, it is impossible to carry on drilling operations advantageously with the cable-tool system on account of the constant caving of the walls of the hole. In such localities, the hydraulic rotary system is used.

The rotary equipment uses the same type of boiler, engine and derrick as the cable-tool system. The derrick is usually taller and, generally, is not built so strongly.

Drilling is accomplished by a bit at the end of a drilling stem, which is composed of lengths of pipe screwed together. The top

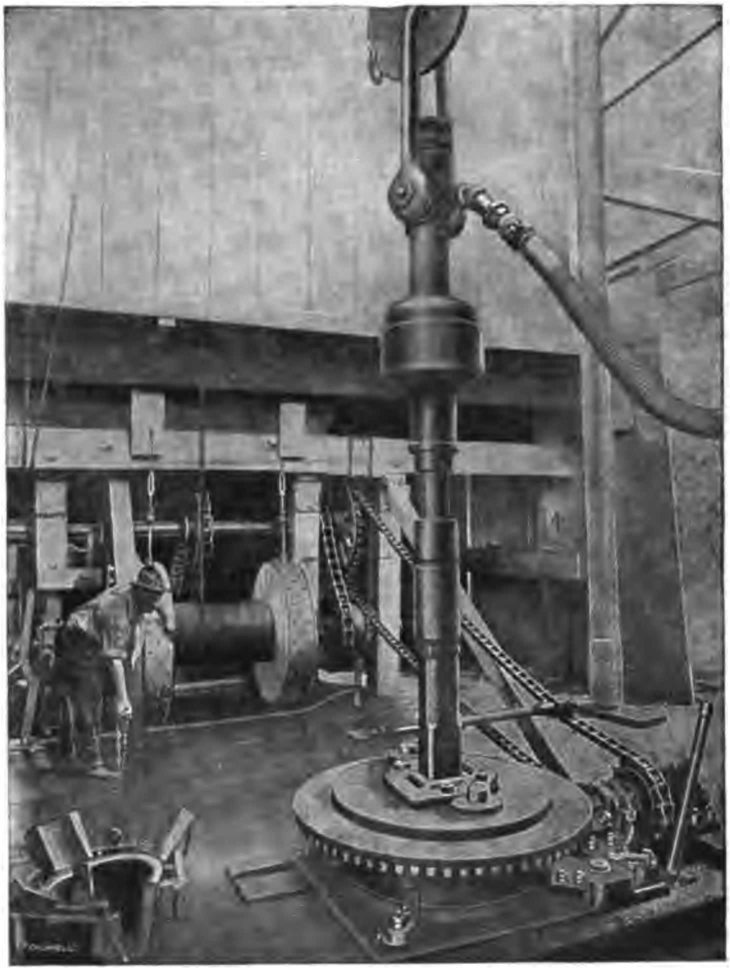

Fig. 40.—Rotary.

length of pipe is square, the remainder is round. The drilling stem is removed to set casing and to sharpen or change bits. The removal is accomplished rapidly, the stem being separated into sections of four or five pipe lengths, and stood back in the derrick.

The drilling stem and bit is rotated by means of a rotary which is shown in fig. 40. It consists simply of a rotating table centered

over the hole and driven by a chain drive. The square section of the drill stem is clamped into the rotary.

The walls of the hole are kept from caving by means of circulating mud, which is forced by pumps through a swivel at the top of the drill stem, down through the stem, and back on the outside of the stem. The circulating mud "plasters up" the walls of the hole so that they will stand while the drilling stem is being removed and the casing set. As the mud comes back to the surface it is led through a flume, where the sand and coarse cuttings settle, back into the mud pit whence it is again pumped through the hole.

Fig 41. Fish-tail bit.

Fig 42.—Drag bit.

The ordinary or fish-tail bit (fig. 41) can make very rapid progress in unconsolidated rocks but is valueless for drilling in hard rock. For the latter purpose, three different types of bits have been developed. The drag or admantine bit (fig. 42) has the drilling points turned in the opposite direction from those of the fish-tail bit. Admantine or chilled shot is thrown into the hole and the bit dragging this over the rocks wears it away. The Sharpe-Hughes bit (figs. 43 and 44) consists of two rotating cones which have many cutting edges. The core-barrel is shown in fig. 45, which is self-explanatory. Chilled shot are used as the cutting agent as with the drag-bit.

Casing is handled as in the cable-tool system but only one or two strings are needed in most wells.

Fig. 43. — Sharpe-Hughes Rotary bit.

Combination System.

In regions where the drilling must penetrate considerable thickness of both very hard and very soft rocks, a combination of both the cable-tool and the rotary systems is used. The derrick is constructed so as to accommodate the tools and equipment for both methods.

Fig. 44. — Sharpe-Hughes rotary bit showing drilling surfaces.

Hydraulic Circulating System.

Recently the principle of the circulating mud column has been applied to the cable-tool system. The mud is pumped through a hose and a circulating head, down through the casing and returns on the outside of the casing. The casing must follow the bit quite closely in order to give the mud column force enough to wash out the cuttings and this makes drilling by this process very slow.

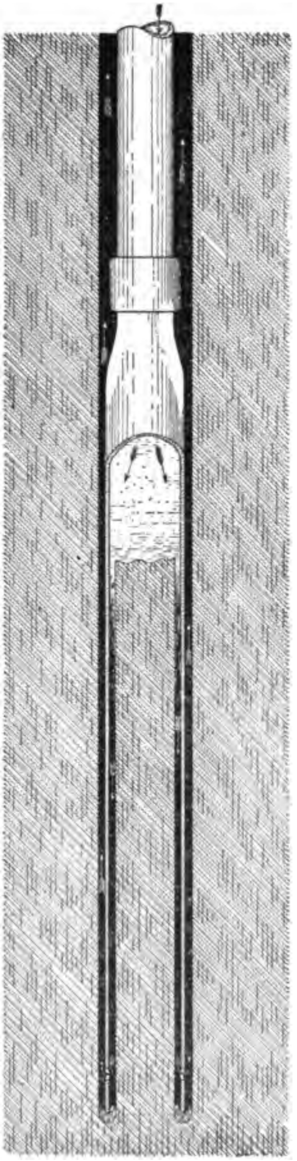

Fig. 45.—Core-barrel.

Production.

After oil has been found in a well, the production is a very simple matter. The well may flow naturally, in which case all that is necessary is to provide the proper flow lines and tankage.

Most wells do not have sufficient pressure to flow and must be pumped. A string of tubing, two or three inches in diameter, with the pump barrel at the bottom is lowered into the well and anchored at the surface. Rods passing through the tubing operate the pumps. The rods are actuated by the walking beams of the drilling rig in newly finished wells, and by pumping jacks for the older wells after a sufficient number have been completed to make the installation of a pumping power advisable. A pumping jack is shown in fig. 46, and its action is apparent from the figure.

Where several wells are to be pumped in a small area, a pumping power is installed. These powers are of several different types. The most common type consists of a horizontal wheel driven by a belt from a gas or gasoline engine. Eccentrics below the wheel give an oscillatory motion to the pulls attached to them and so operate the pumping jacks. The jacks are connected to the powers by means of jointed rods of iron or steel, known as sucker rods. These are held off the ground by posts which carry them in straight lines between the power and the jack. The tops of the posts are cut into a V in which the

rods rest. The use of the angle irons, similar to a jack, but operating in a horizontal plane, makes it possible to pump wells situated in all directions from the power.

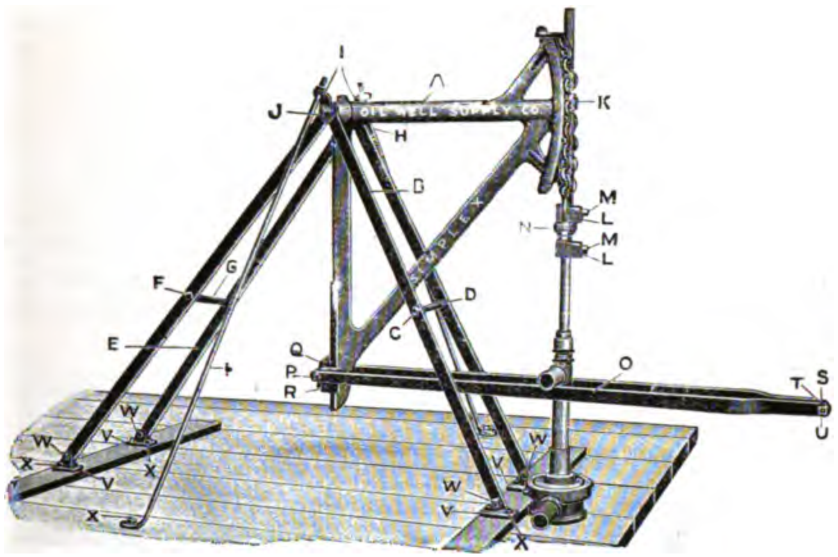

Fig. 46.—Pumping jack.

The production of oil wells may be increased by "shooting", which consists of the explosion of a charge of nitro-glycerine in the producing sands. The nitro-glycerine is carefully lowered into the wells in cylindrical cans. The charge is exploded by dropping a weight upon it or by a fuse. The amount of nitro-glycerine varies greatly with conditions ranging from 10 to 200 quarts or even more. Considerable care must be used in placing the charge since there is danger of shattering the rock above the sand and allowing water to "drown out" the oil, or else caving the hole. The casing is usually pulled up several feet before the shot is fired to avoid injuring it.

The action of the nitro-glycerine is to shatter the oil sand so that larger migration channels are opened in it and the oil can flow more rapidly into the well. Shooting is most valuable in hard, close-grained oil sands.

Old wells whose production has become very low may often be "brought back" by cleaning out. The pores in the oil sand become clogged with mud or by the deposition of salts from solution, or by deposition of paraffine from the oil itself. The deposition of paraffine is probably the greatest cause of the clogging of the sand. It may be removed by the action of steam forced into the well. A

small charge of nitro-glycerine also has the effect of clearing the sand, probably as much on account of the heat developed by the explosion as by its shattering action on the oil sand.

CHAPTER IV.

THE GEOLOGY OF THE MID-CONTINENT FIELDS.

The Mid-continent oil and gas fields, as considered in this book include all oil and gas developments in Kansas and Oklahoma, those in Texas—with the exception of the salt dome fields of the Gulf Coast—and the fields of the Sabine uplift in northwestern Louisiana.

GENERAL GEOLOGIC FEATURES OF THE MID-CONTINENT FIELDS.

The rocks of Kansas, Oklahoma and Texas are predominantly sedimentary. Igneous rocks in quantity are known only in a buried granite ridge in Kansas; in the Arbuckle and Wichita mountains in Oklahoma; in the Llano-Burnet mountains in central Texas, in trans-Pecos Texas, and in small isolated areas in south-central Texas.

The most striking feature of the areal geology of the three states is the broad belt of Pennsylvanian and Permian rocks, which occupies the eastern two-thirds of Kansas, nearly all of Oklahoma, and extends in a broad belt through central Texas to within a comparatively short distance of the Rio Grande. These Pennsylvanian and Permian rocks have in general a westward dip, which varies from about 20 feet to about 100 feet to the mile along the eastern margin of their outcrop. This dip decreases to the west until the beds are flat, and in the extreme western part of the Permian outcrop the beds have a gentle east dip. In other words, the Pennsylvanian-Permian rocks occupy a broad geo-syncline between the Ozark and Ouachita mountains (and possibly a third system of buried mountains farther to the south) on the east, and the Rocky mountains on the west. The Ozark, Ouachita, Arbuckle, Wichita and Llano-Burnet mountains bring older rocks to the surface, on the margin of or within the Pennsylvanian-Permian area. To the southeast and south of the Pennsylvanian-Permian area is a broad belt of younger formations ranging from Comanchean to Recent in age, which dip to the southeast at a rate of about 20 feet to the mile. To the west and northwest is another belt of Cretaceous and Tertiary rocks, which were derived from the Rocky Mountains and, in general, dip eastwardly away from the mountains. Trans-Pecos, Texas belongs to the Cordilleran (Rocky Mountain) geologic province and the geologic conditions vary widely from those in the remainder

of the area. Up to the present, only the Pennsylvanian-Permian and Cretaceous areas are important in oil and gas production (except for the dome fields) which are not considered in this book), but the geology of the whole area of the three states is given in some detail in the following pages.

GEOLOGY OF KANSAS.

The surface rocks of Kansas are all of sedimentary origin. Igneous rocks of probable pre-Cambrian age are known in a buried ridge, which extends east of north from northern Butler county to and beyond the Nebraska state line.

Somewhat more than one-third of the area of the state, the eastern portion, is occupied by the outcrop of Pennsylvanian and

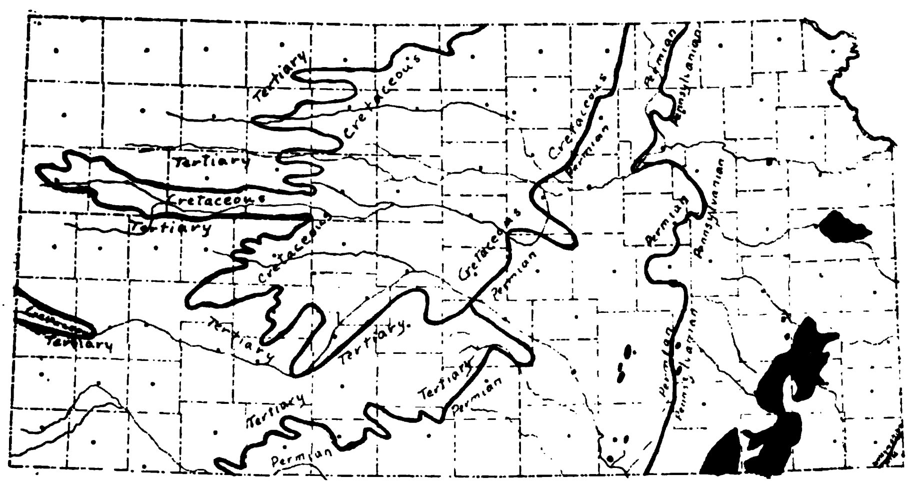

Fig. 47.—Sketch map of Kansas showing areal geology.

Permian rocks which dip very gently west and northwest. The western portion is underlain by rocks of Cretaceous and Tertiary age which lie very nearly flat but have a slight dip away from the Rocky mountains. The areal geology is shown in the accompanying sketch map (fig. 47) and also on the general map (Pl. I.)

The following table summarizes the stratigraphy of Kansas:

Cenozoic	Quaternary	Recent — Alluvium, sand dunes.	
		Pleistocene — Glacial deposits in northeastern part of state.	
	UNCONFORMITY.		
	Tertiary	Pliocene Miocene	Ogallala—Gravels, sands and clays.

		UNCONFORMITY.		
Mesozoic	Cretaceous	Montana	Pierre shale.	
		Colorado	Niobrara—Limestone and chalk.	
			Benton—shale.	
		Dakota	Dakota—sandstone.	
		UNCONFORMITY.		
	Comanchean (Lower Cretaceous)	Washita	Kiowa—shale.	
			Cheyenne—sandstone.	
		UNCONFORMITY.		
	Permian	Cimarron (Red Beds) Series	Greer—gypsum and red shale.	
			Woodward—red shales and sandstones.	
			Cave Creek—gypsum and red shale.	
			Enid—red shales.	
			Wellington—blue shales.	
		Big Blue Series	Marion	Abilene conglomerate.
				Pearl shale.
				Herington limestone.
				Enterprise shale.
				Luta limestone.
			Chase	Winfield limestone.
				Doyle shale.
				Fort Riley limestone.
				Florence flint.
				Matfield shale.
				Wreford limestone.
			Council Grove	Garrison shale.
				Cottonwood limestone.
Paleozoic		Missouri	Wabaunsee	Eskridge shale.
				Neva limestone.
				Elmdale shale
				American limestone.
				Admire shale.
				Emporia limestone.
				Willard shale.
				Burlingame limestone.
			Shawnee	Scranton shale.
				Howard limestone.
				Severy shale.
				Topeka limestone.
				Calhoun shale.
				Deer Creek limestone.
				Tecumseh shale.
				Lecompton limestone.
				Kanwaka shale.
			Douglas	Oread limestone.
				Lawrence shale.
				Iatan limestone.
				Weston shale.

Paleozoic	Pennsylvanian		Lansing	Stanton limestone.
				Vilas shale.
				Plattsburg limestone.
				Lane shale.
			Kansas City	Iola limestone.
				Chanute shale.
				Drum limestone.
				Cherryvale shale.
				Winterset limestone.
				Galesburg shale.
				Bethany Falls limestone.
				Ladore shale.
				Hertha limestone.
		Des Moines	Marmaton	Pleasanton shale.
				Coffeyville limestone.
				Walnut shale.
				Altamont limestone.
				Bandera shale.
				Pawnee limestone.
				Labette shale.
				Fort Scott limestone.
			Cherokee shales, sandstones and coal.	

UNCONFORMITY.

Mississippian—Boone chert—In extreme southeastern corner of state.

UNCONFORMITY.

Ordovician } Do not outcrop.
Cambrian }

UNCONFORMITY.

Pre-Cambrian —Does not outcrop.

A very brief discussion of the formations, from the lowest upwards, follows:

PRE-CAMBRIAN ROCKS.

The pre-Cambrian rocks certainly underly the whole state but do not outcrop within its boundaries. However, they come within a few hundred feet of the surface in a buried ridge which extends east of north from northern Butler county, through Marion, Chase, Morris, Wabaunsee, Riley, Pottawatomie and Nemaha counties and into Pawnee county, Nebraska.

This granite ridge is extremely important from the standpoint of oil and gas production since it produces a pronounced structure which was considered as being very favorable for production until it was discovered that the granite came unexpectedly near the surface and cut out the possibly productive sands.

The rocks immediately above the granite appear, from well cuttings to be unaltered Pennsylvanian sediments so the granite seems

to represent an old land mass, which was submerged only in late Pennsylvanian times. The surface of the granite plunges off very rapidly to the east of the ridge but to the west the descent is much more gentle, since granite has been encountered in a well a considerable distance west of the ridge. Along the ridge the surface of the granite is very uneven, and the elevations of the top of the granite in wells a short distance apart vary by hundreds of feet. The materials of the "ridge" are those in general of typical red granite. Quartz porphyry and chlorite schist have also been identified.

The following list gives some of the locations where granite has been encountered and the depths to the granite:

Zeandale	Sec. 27,	T. 10S.	R. 9E,	958 feet	
Zeandale	Sec. 26.	T. 10S.	R. 9E.	945 feet	
Elmdale	Sec. 34.	T. 19S.	R. 7E,	1,707 feet	
Elmdale	Sec. 2.	T. 20S.	R. 7E.	1,870 feet	
Webaunsee	Sec. 1.	T. 11S.	R. 9E.	1,170 feet	
Onaga	Sec. 34.	T. 6S.	R. 11E.	1,035 feet	
Council Grove	Sec. 34,	T. 17S.	R. 7E.	2,500 feet	
Council Grove	Sec. 24.	T. 15S.	R. 7E,	2,513 feet	
Wamego	Sec. 12,	T. 10S.	R. 10E,	2,300 feet	(about)
Burns	Sec. 24.	T. 23S.	R. 5E.	2,326 feet	
Alto Vista	Sec. 9.	T. 13S.	R. 8E,	2,120 feet	
Seneca	Sec. 34.	T. 2S.	R. 12E,	586 feet	
Winkler	Sec. 2.	T. 7S.	R. 5E,	2,520 feet	

The presence of granite so near the surface condemns much territory from the standpoint of production of oil and gas. The uncertainty as to the depth of the granite in most places on the west side of the "ridge" and the probability of the lower Pennsylvanian sands being absent makes prospecting in this area hazardous, except near the southern end of the ridge. On the east side of the ridge there is a better chance for production since the slope of the granite surface is much more rapid and the lower Pennsylvanian sands are probably present.

LOWER PALEOZOIC ROCKS.

The Cambrian and Ordovician rocks at their outcrop in south-central Missouri and in Arkansas are 2,000-2,500 feet thick and they dip back northwestward under the Kansas area. However, they thin considerably to the northwest, since nowhere in southeastern Kansas or the adjacent portion of Oklahoma is the section between the Mississippian and the granite, as shown by well-logs, more than 1,000 feet and it is usually much less. It is impossible to state which part of the exposed section is represented by the buried rocks in southeastern Kansas. These rocks are almost certainly absent over the granite "ridge" area and their presence to the west has not been proven.

Silurian and Devonian rocks are not present so far as is known.

MISSISSIPPIAN SYSTEM.

A small area in the southeastern corner of the state is underlain by the Boone chert of Mississippian age. This formation is the "Mississippi lime" of the drillers and is important as being the lower limit of oil production. Some gas is obtained from the formation in Chautauqua county. The Boone does not extend over the granite "ridge" and its extension to the west is problematic.

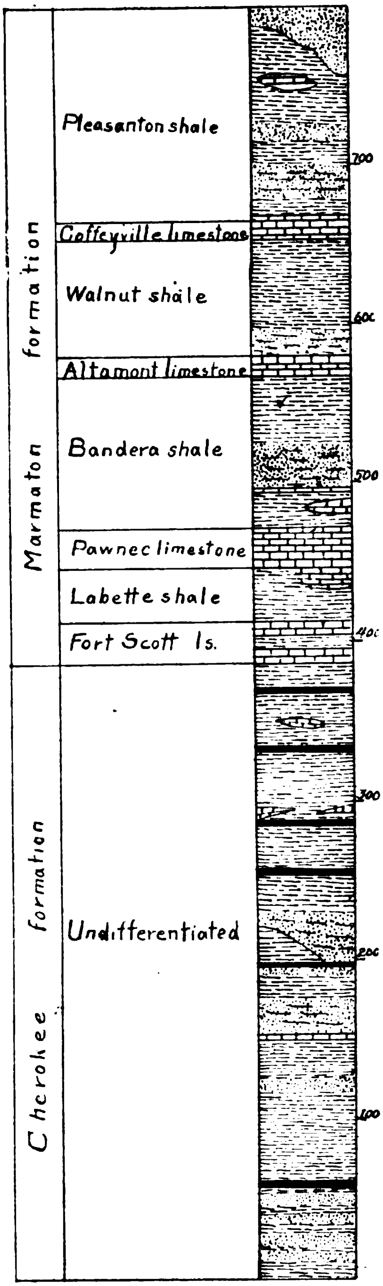

Fig. 48.—Columnar section of Cherokee and Marmation formation.

PENNSYLVANIAN SYSTEM.

The rocks of the Pennsylvanian system are the most important in connection with oil and gas since nearly all the accumulations occur in this system which also outcrop over most of the productive area. On this account the different members are noted individually, and their character, thickness and extent are given in summarized form. The nomenclature of Bulletin 3 of the State Geological Survey of Kansas is used throughout and the information given is summarized from that report. The classification generally adopted for the Pennsylvanian of Kansas is shown in the table on a preceding page and need not be repeated here. The formations and members are considered from the lowest upwards.

Des Moines Group.

The Des Moines group outcrops in a belt in southeastern Kansas, extending from Montgomery county northeastward through Labette, Cherokee, Neosho, Crawford, Bourbon and Linn counties. Its thickness varies from place to place, but, as a rule, is from 600 to 800 feet. It

is divided into two formations, the Cherokee shale and the Marmaton formations. A diagrammatic section of these formations is shown in fig. 48.

Cherokee Shale—The Cherokee shale consists of a thickness of 400 to 500 feet of shale, with irregular sandstone beds, a few thin limestones and thin coals. The sandstones of this formation are the source of most of the oil and gas in southeastern Kansas, and northeastern Oklahoma. The most important sand (or sand horizon) is known as the Bartlesville and has a wide extent.

Marmaton Formation—The Marmaton formation consists of alternating limestones and shales with minor amounts of sandstone associated with the shales. The limestones are persistent for long distances and they, as well as the intervening shales, are recognized as distinct members.

Fort Scott limestone: consists of a lower limestone 5 to 18 feet thick, a shale 7 to 8 feet thick, and an upper limestone 10 to 12 feet thick; total average thickness about 30 feet; outcrops in narrow belt from Chetopa northeastward to near Fort Scott.

Labette shale: consists of clay shale and sandy shale grading into clayey sandstone, ranging in thickness from 20 to 60 feet; thickens to south.

Pawnee limestone: consists of massive, fine-grained limestone; average thickness about 45 feet, outcrops in escarpment from west of Chetopa northeastward to near Fulton.

Bandera shale: consists of clay shale, grading locally into sandy shale and sandstone and thin coal; thickness from 60 to 120 feet, thinning southward into Oklahoma, where it pinches out near Oologah; outcrops in belt 3 to 8 miles wide; probably contains Peru oil and gas sand.

Altamont limestone: consists of hard, massive siliceous limestone; thickness from 3 or 4 to 10 feet, thickening southward into Oklahoma.

Walnut shale: consists principally of clay shale with very little sand; thickness about 70 feet; width of outcrop 1 to 8 miles.

Coffeyville limestone: thin, persistent limestone, 8 to 10 feet thick in vicinity of Coffeyville, thickens to north.

Pleasanton shale: consists of shales, with sandstones and some thin, discontinuous limestones; average thickness about 120 feet; probably contains producing oil sands in Paola and Rantoul fields.

Missouri Group.

The Missouri group is differentiated from the underlying Des Moines group by the presence of more limestone, less sandstone and less coal, and by faunal differences. Locally the two groups are sep-

arated by an unconformity. The individual beds of the Missouri group are more persistent and, as a rule, more uniform in thickness than those of the Des Moines. The group outcrops in a broad belt west of the Des Moines group. The west boundary extends nearly southward from Marshall county to Cowley county. The total thickness in the central part of the state is about 2,000 feet, in the southeastern part about 1,500. These rocks thin underground to the west. The group is divided into five formations, the Kansas City, Lansing, Douglas, Shawnee and Wabaunsee.

Kansas City Formation—The Kansas City formation outcrops as an irregular but well-defined belt, trending west of south from Kansas City to Montgomery county and on into Oklahoma. The thickness varies from 200 to more than 300 feet. The columnar section of the formation is shown in fig. 49. The formation consists principally of limestone and is divided into five limestones with four shale members as follows:

> *Hertha limestone*: (Erroneously called Bethany Falls limestone in early Kansas reports) consists of thick-bedded gray, crystalline limestone; thickness 22 feet at Uniontown, thinning to south and disappearing near Mound Valley; forms pronounced scarp above Pleasanton shale flat.
>
> *Ladore shale*: consists of clayey or sandy shale grading locally into shaley sandstone or limestone; varies in thickness from 3 feet at Kansas City to 40 feet or more near the Oklahoma line; in south part of outcrop rests directly on Pleasanton shale.
>
> *Bethany Falls limestone*: consists of two beds, the lower thick-bedded, locally oolitic in the northern part of its outcrop, non-fossiliferous limestone; the upper, thin-bedded fossiliferous limestone; thickness 22 or 23 feet at Kansas City, thinning to 4 feet at Mound Valley and disappearing farther south.
>
> *Galesburg shale*: consists of clay shale locally grading into sandy or bituminous shale; thickness 5 or 6 feet at Kansas City, thickening southward to 60 feet in northwestern Labette county.
>
> *Winterset limestone*: (Formerly called Dennis limestone), consists of blue, thin-bedded limestone with buff shale partings, with much dark-colored chert in upper part; thickness about 30 feet.
>
> *Cherryvale shale*: consists of clay or limey shale with thin lenticular limestones; thickness 125 feet near south line of state decreasing northward to about 25 feet.
>
> *Drum limestone*: consists of oolitic limestone; varies greatly in thickness, from a very few feet to 80 feet.
>
> *Chanute shale*: consists generally of clay shale, but locally is represented almost entirely by sandstone, while in other places considerable limestone occurs in the formation; some workable

coals and other thin seams are present; thickness in south part of state about 100 feet, thinning northward to about 25 feet at Kansas City.

Iola limestone: consists of light gray somewhat crystalline, massive limestone; thickness between Iola and Kansas City, 30 to 40 feet, but thinning and disappearing to the southwest and northeast.

Lansing Formation—The Lansing formation is separated from the Kansas City formation below by a marked faunal break and from the Douglas formation above on account of lithologic differences. The outcrop is a rather narrow belt extending from the vicinity of Sedan, Chautauqua county, northeast to the vicinity of Leavenworth. The thickness of the formation is about 140 feet in the north part of its outcrop and somewhat less toward the south. The Lansing formation consists of three shale and two limestone members. The columnar section is shown in fig. 49.

Lane shale: consists principally of clay shale, more sandy toward the top; average thickness about 50 to 60 feet but increasing to 150 feet to the south.

Plattsburg limestone: (Called Allen limestone in early Kansas reports) generally consists of massive, crystalline, fossiliferous limestone, breaking rapidly into small angular fragments and containing considerable chert in the upper part; thickness varying from 4 or 5 to 75 or 80 feet in different parts of its outcrop and disappearing in Oklahoma and Missouri.

Vilas shale: consists of clay and sandy shale showing a thickness of 125 feet at Vilas but

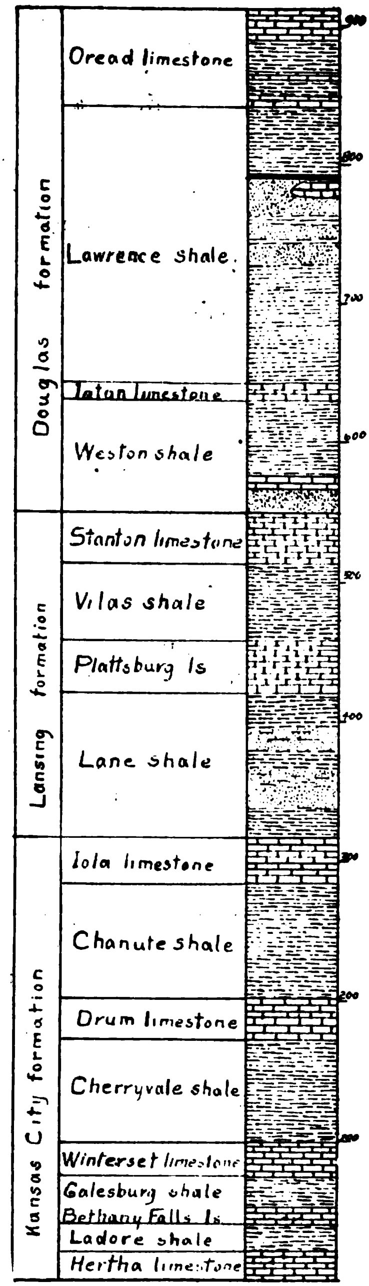

Fig. 49—Columnar section of the Kansas City, Lansing and Douglas formations.

thinning rapidly to the northeast and southwest to about 5 feet in northwestern Missouri and at Neodesha.

Stanton limestone: consists of massive limestone beds separated by thin, slaty beds with a total thickness varying between 20 and 40 feet. The Stanton with the underlying Plattsburg forms a pronounced escarpment extending from near Caney northeastward through Neodesha, Altoona and Benedict and on into Missouri.

Douglas Formation—The Douglas formation consists principally of shale with an important limestone member at the top and a thin limestone near the middle. The thickness of the formation varies from about 350 to 550 feet, the average being about 425 feet. The columnar section is shown in fig. 49. The formation includes four members.

Weston shale: consists of sandy and clay shale with a thickness of 60 to 100 feet.

Iatan limestone: (Called Kickapoo limestone in early Kansas reports) consists of thin and irregularly bedded to massive limestone, 15 feet thick in Doniphan county, but much thinner to the south.

Lawrence shale: consists of clay shale with much sandstone, and thin limestones and coal seams, 150 to 300 feet thick; it thickens and is nearly all sandstone in the southern part of its outcrop.

Oread limestone: consists of three limestones and two shales. The lower limestone is massively bedded, buff to gray in color, and 8 to 12 feet thick; the lower shale is blue or drab and 20 to 60 feet thick; the middle limestone is less than 3 feet thick but is quite persistent; the upper shale is blue gray to black, bituminous, and 6 to 15 feet thick; the upper limestone is a thin-bedded, cherty, buff limestone 10 to 25 feet thick. The whole formation varies from about 50 to 70 feet in thickness. The Oread forms a pronounced escarpment above the soft shales underneath.

Shawnee Formation—The Shawnee formation consists of alternating shales and limestones with the shales forming three-fourths or more of the formation. The total thickness is from 400 to 500 feet. The columnar section is shown in fig. 50. Nine members, five shales and four limestones are recognized.

Kanwaka shale: consists of clay shale and sandstone, with some thin seams of coal. The formation thickens and is more sandy to the south and has been called the Elgin sandstone near the Kansas-Oklahoma state line. The formation varies in thickness from 50 to 140 feet.

Lecompton limestone: consists of thin limestone beds with shale partings having a total thickness of 15 to 30 feet.

Tecumseh shale: consists of sandy shale and shaly sandstone, 40 to 70 feet thick.

Deer Creek limestone: consists of three thin limestone beds separated by shales, with a total thickness of 20 to 30 feet.

Calhoun shale: consists principally of blue-gray shale with some thin blue limestones; thickness about 50 feet.

Topeka limestone: consists of blue and buff limestone with interbedded shales all weathering to buff, total thickness 20 to 25 feet; does not form strong escarpment.

Severy shale: consists principally of clay shale, but is locally quite sandy and contains some thin coal beds; total thickness 40 to 60 feet.

Howard limestone: consists of two limestone beds separated by 1 to 2 feet of shale; total thickness 3 to 7 feet.

Scranton shale: consists of clay shale with sandy shale and sandstone; thickness, 160 to 200 feet.

Wabaunsee Formation — The Wabaunsee formation consists of eight members, four limestone and four shales. The total thickness is about 500 feet. The columnar section is shown in fig. 50.

Burlingame limestone: consists of two massive limestone beds separated by a thin shale; total thickness 7 to 12 feet.

Willard shale: consists of blue and yellow shale with thin friable limestones; thickness 45 to 55 feet.

Emporia limestone: consists of two hard, blue limestones separated by about 4 feet of shale; total thickness about 9 feet.

Admire shale: consists of a suc-

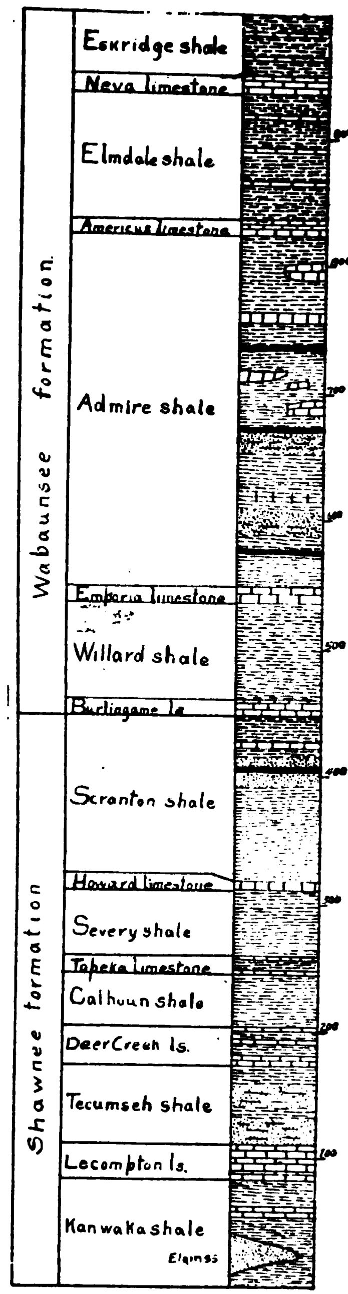

Fig. 50.—Columnar section of the Shawnee and Wabaunsee formations.

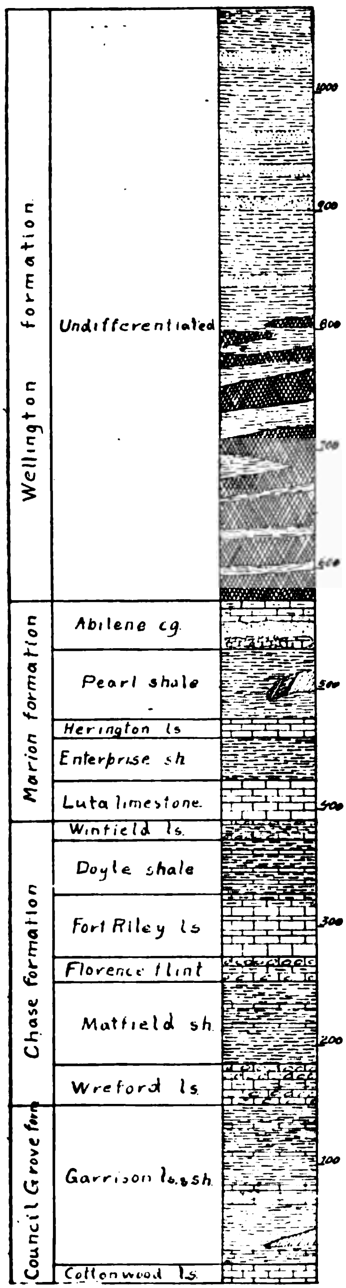

Fig. 51—Columnar section of the Big Blue series.

cession of shales and sandstones with some thin limestones; total thickness about 300 feet.

Americus limestone: consists of a single bed of limestone about 9 feet thick.

Elmdale shale: consists of variegated shales with thin limestones; thickness about 130 feet.

Neva limestone: consists of two beds of massive bluish gray limestone, each about 4 feet thick separated by 4 feet of shale. The formation thins to the north, and thickens and grades into sandstone in Oklahoma.

Eskridge shale: consists of green, brown and yellow shale about 30 feet thick.

PERMIAN SYSTEM.

The Permian system in Kansas outcrops in a triangular area with its apex to the north, west of the Pennsylvanian area. The rocks lie conformably on the Pennsylvanian below and pass unconformably under Comanchean and Cretaceous rocks to the west. The system is divided into two distinct groups: (1) the lower or Big Blue group, consisting of marine limestones and shales generally similar to those of the underlying Pennsylvanian; but with the limestones more cherty and the shales generally less bituminous; (2) and the upper or Cimarron group consisting of principally non-marine Red-beds with important gypsum beds. The classification is given on a previous page.

Big Blue Group.

The Big Blue group, consisting of the non-red marine limestones and shales of the Permian is divided into four formations, the Council Grove, Chase, Marion and Wellington. The columnar section of the series is shown in fig. 51.

Council Grove Formation—The Council Grove formation consists of one limestone and one shale member.

Cottonwood limestone: consists of light gray to buff, massively bedded limestone containing enormous numbers of *Fusulina secalica* in the upper part. It extends entirely across the state with very little lithologic change. The average thickness is about 6 feet.

Garrison limestone and shale: consists of yellowish shales with intercalated thin limestones; thickness 135 to 150 feet. The member contains one gypsum bed.

Chase Formation—The Chase formation consists of cherty limestones and shales. The outcrop produces the topographic feature known as the Flint Hills. The total thickness is about 230 to 275 feet. It is made up of six distinct members.

Wreford limestone: consists of massive limestones and chert. In most places it has an upper and a lower cherty bed with a middle bed of purer limestone. In places this bed is replaced by shale. The entire thickness is 35 to 50 feet.

Matfield shale: consists of 60 to 70 feet of vari-colored shale with thin shaly and cherty limestone.

Florence flint: consists of very cherty limestone with a band of white cellular limestone near the middle; thickness about 20 feet.

Fort Riley limestone: consists of massive buff limestone with thin shaly layers. The outcrop is distinguished by numerous small sink holes. The thickness is about 40 to 45 feet.

Doyle shale: consists of vari-colored shale with thin limestone layers; thickness about 60 feet.

Winfield limestone: consists of two massive, cherty limestone beds separated by yellowish shale. The thickness in the southern part of the outcrop is 20 to 25 feet, but it thins to the north.

Marion Formation—The Marion formation is similar to the Chase but the limestones are less cherty and it is faunally distinct. The presence of limestones, and its fossiliferous character, as well as the absence of salt distinguish it from the overlying Wellington. The outcrop produces a rolling surface, as distinguished from the prominent escarpments of the Flint Hills to the east. The formation has a thickness of about 150 feet and has been divided into five members, which have been mapped through only a portion of their outcrops.

Luta limestone: consists of more or less cellular, soft, gray limestone, with siliceous geodes and some cherty bands. The Luta is about 30 feet thick in the central Kansas, but it thins to the south disappearing about the Kansas-Oklahoma line.

Enterprise shale: consists of variegated shales about 35 feet thick.

Herington limestone: consists of massive buff fossiliferous limestone, 12 to 15 feet thick.

Pearl shale: consists of about 70 feet of soft green, blue and reddish shale.

Abilene conglomerate: is an irregular, somewhat conglomeratic limestone which near Abilene is a calcareous conglomerate containing some sand and sandstone pebbles. Near Herington and Marion, it is a heavy, hard, perhaps dolomitic, stone composed of orange, yellow and gray masses firmly united in a light, gray cementing material.

Wellington Formation—The Wellington formation, consisting of blue, gray and slate colored shales with important salt beds in the lower portion, makes up about half of the Big Blue series. There are thin, soft sandstone beds and rarely, thin lenticular limestones, but no beds sufficiently resistant and persistent to permit the formation being sub-divided into members. The outcrop is triangular in shape with the apex about Smoky Hill river and the base along the Kansas-Oklahoma state line. In the southern part of the outcrop, the formation passes under the Redbeds but farther north is covered by the overlap of Cretaceous beds. The thickness of the formation is difficult to determine but, as shown by well logs, is about 800 feet in the southern part of its outcrop decreasing to about 500 feet to the north. The salt beds are contained in the lower part of the formation, which does not outcrop.

Cimarron Group.

The outcrop of the Redbeds in Kansas is the northward extension of the great belt of Redbeds rocks of Texas and Oklahoma. The group is much thinner in Kansas than to the south, where the conditions favorable for the deposition of Redbeds began much earlier. The whole group consists of red shales, with soft and generally lenticular, red to white sandstones, and with several beds of gypsum, some of which are persistent for many miles. One dolomite bed also extends for a great distance along the outcrop in Oklahoma and Kansas.

The group is subdivided into formations and members but these have, as yet, little or no connection with oil and gas production. Therefore only the briefest statement of the classification is given.

The Cimarron group in Kansas is divided into four formations, and these into twelve members as follows (beginning at the bottom.)

Enid Formation.

a. Harper sandstone, soft red sandstones and red sandy shale 300 feet.

b. Salt Plain shale, red, saliferous clay shale, 155 feet.
c. Cedar Hills sandstone, hard, bright red, fine-grained sandstone, 50 to 60 feet.
d. Flowerpot shale, variegated shales, mostly red, gypsiferous, 100 feet.

Cave Creek Formation—(Blaine formation of Oklahoma.)
a. Medicine Lodge gypsum, massive, fine-grained to selenitic gypsum, 2 to 30 feet.
b. Jenkins shale, red clay shale, 5 to 50 feet.
c. Shimer gypsum, selenitic to massive gypsum, 4 to 25 feet.

Woodward Formation.
a. Dog Creek shale, dull-red, clay shale, 30 feet.
b. Whitehorse sandstone, very fine, cross-bedded, red to gray sandstone, 175 to 200 feet.
c. Day Creek dolomite, hard, white to pink dolomite, 1 to 5 feet.

Greer Formation.
a. Hackberry shale, maroon clay shale, 20 feet.
b. Big basin sandstone, red to gray sandstone, 12 feet.

COMANCHEAN (LOWER CRETACEOUS) SYSTEM.

Rocks of the Comanchean system outcrop in a narrow belt in Barber, Comanche, Kiowa, Clark and Meade counties. These beds appear to represent the upper part (Washita division) of the great series of Comanchean rocks in Texas, and small isolated areas of rocks of the same age in western Oklahoma indicate that the series was once continuous between Kansas and Texas. A small area of rocks along Smoky Hill river in Saline and McPherson counties is probably of the same age as the larger body farther south.

The Comanchean rocks of Kansas are divided into two formations:

1. The *Cheyenne sandstone* which lies unconformably on the Redbeds, consists of rather coarse-grained, friable sandstone, usually gray to white in color, but locally mottled and striped with brighter colors. The outcrop is rugged and carved into various striking erosional forms. Fossil wood and imprints of leaves are common. The thickness varies from about 40 to 70 feet.

2. The *Kiowa shale* lies conformably on the Cheyenne sandstone, where the latter is present, but in part of the area, rests directly on the Redbeds. The lower part of the formation is calcareous shale or argillaceous limestone filled with invertebrate fossils; this grades upward into dark, laminated, clay shale and this into yellowish or pinkish limestones. The average thickness of the formation is about 125 feet with an observed maximum of 150 feet.

CRETACEOUS SYSTEM.

The rocks of the Cretaceous system cover large areas in north-central Kansas and appear in smaller tracts and outliers in several places in the western part of the state. The system consists of clay and sandy shale, chalky limestone and sandstone in order of importance. The thickness of the system in Kansas is about 1,300 feet. The Cretaceous rocks are divided into four formations, two of which are divided into members. The classification is as follows:

Cretaceous System
- Pierre Shale
- Niobrara formation
  - Smoky Hill chalk member.
  - Fort Hays limestone member.
- Benton formation
  - Carlile shale member.
  - Greenhorn limestone member.
  - Granerous shale member.
- Dakota Sandstone

Dakota sandstone—The Dakota formation outcrops in a belt from Washington county south and southwest to Arkansas river in Rice and Barton counties, and up the Arkansas to Ford county. It appears in patches along the Cimarron and its tributaries in the extreme southwestern part of the state. The formation rests upon the eroded surface of the Redbeds or the Comanchean rocks in the southern part of the state and on the Wellington formation farther north.

The Dakota consists typically of massive sandstone but contains considerable shale irregularly distributed and, in the upper portion, some gypsum and lignite. The formation is the great water-bearing horizon of the northern Great Plains, but so far, has not been an important oil or gas producer. The total thickness ranges from 200 feet to more than 300 feet.

Benton formation—The Benton formation outcrops in a broad belt of gently undulating country from Washington and Republic counties on the north to Ford, Hodgeman and Kinney counties in the southwest. Here it passes under the Tertiary beds but reappears along the Arkansas river in Kearny and Hamilton counties. The formation consists principally of shale, with intercalated sandstones and limestones. The total thickness varies but averages about 400 feet. The Benton formation in Wyoming, where it is much thicker than in Kansas, contains sandstone members which are important oil producers, but no production has been had from the Benton formation in Kansas. The Benton is divided into three members.

1. *Graneros shale*: consists of dark, clay shale, rather bituminous and slaty. It is only 20 to 30 feet thick in central Kanses but thickens rapidly toward the west.
2. *Greenhorn limestone*: consists of calcareous beds, including limy shale, soft, chalky limestone, and thin beds of hard, resistant limestone. The thickness varies from 40 to 60 feet.
3. *Carlile shale*: consists almost entirely of shale with some thin limestone beds. The lower part is quite fossiliferous, and has a thickness of 150 feet.

Pierre Shale—Although the Pierre shale underlies all of northwestern Kansas, it is in most cases covered by Tertiary beds and outcrops only locally. The formation consists of dark, bluish, gray shale, weathering to a brownish color. The maximum thickness in Kansas is not more than 200 feet.

TERTIARY AND LATER DEPOSITS.

An area of several thousand square miles in western Kansas is covered by a mantle of sand, gravel, and limy clay which is classed as the Ogalalla formation, of Pliocene and possibly of late Miocene age. These beds are in most places more or less cemented by calcium carbonate forming what are known as "mortar beds." The thickness varies from practically nothing to 300 feet or more. There are no well defined stratigraphic horizons in the Tertiary beds and it is impossible to determine anything as to the structure of the underlying rocks from the study of the surface. Except for their hiding any structures which may exist in the lower rocks, the Tertiary beds are unimportant in regard to oil and gas.

QUATERNARY DEPOSITS.

The Quaternary deposits of Kansas may be grouped as follows:

1. *Glacial drift*—This is a mixture of sand, clay, pebbles, covering all or parts of nine or ten counties in the northeastern corner of the state. The larger streams have cut through the drift to the Pennsylvanian rocks beneath but much of the territory is so thickly covered that it is impossible to determine the structure of the Pennsylvanian rocks.
2. *Pleistocene river deposits*—Extensive deposits of sand, gravel and clay deposited during Pleistocene times are present along the major streams. One of the most important of these deposits occupies parts of Marion, McPherson, Harvey and Reno counties, and is known as the McPherson beds.
3. *Loess*—Wind blown material of glacial origin occupies large areas in the region of the glacial drift and in the Tertiary region in northwestern Kansas.

4. *Alluvium*—All Kansas rivers have broad valleys which are filled with clay, sand and gravel.
5. *Sand dunes*—These cover large areas in western Kansas principally along the south side of Arkansas river from Ford to Reno county.

All the Quaternary deposits are important in oil geology only from their covering the bed rocks and preventing any determination of structure.

GEOLOGY OF OKLAHOMA.

The surface rocks of practically all Oklahoma are sedimentary and, except in relatively small areas, are not greatly disturbed. The northeastern corner of the state is part of the Ozark mountain region and the rocks dip to the southwest, west and northwest away from the center of the uplift. Most of the rocks in this area are of Mississippian age. The general westward dip continues to the west into the area of the Pennsylvania rocks and into the Redbeds area for some distance. In the western part of the Redbeds the rocks are very nearly level or dip slightly to the east. In the southern part of the state are three mountain groups, the Ouachita, Arbuckle, and Wichita mountains. These mountain uplifts are composed of older rocks than the Pennsylvanian and Permian. They are much folded and faulted. These older rocks extend out under the Pennsylvanian and Permian to the north and west. To the south of the Ouachita and Arbuckle mountains is an area of Comanchean rocks which dip slightly to the southeast and lap over the upturned edges of the older rocks of the mountains.

From the standpoint of its geology, then, the state is divided naturally into certain districts or provinces and it seems best to discuss them as nearly independently of each other as possible. The districts and their boundaries are as follows:

(1) The Ozark mountain region, or Mississippian area, in northeastern Oklahoma, including approximately the territory east of Grand river and north of the Arkansas.

(2) The Sandstone Hills region, or Pennsylvanian area, including east-central and north-central Oklahoma.

(3) The Ouachita mountains in the southeastern part of the state, including most of the area south of the Ardmore branch of the Chicago, Rock Island & Pacific Railway and east of the main line of the Missouri, Kansas & Texas Railway.

(4) The Arbuckle mountains in the south-central part of the state.

(5) The Red River limestone region including the territory between the Arbuckle and Ouachita mountains on the north and Red river on the south.

(6 The Wichita mountains in southwestern Oklahoma.

(7) The Redbeds, including most of western Oklahoma.

These areas are described in the order named. They are all indicated on the general geologic map (fig. 52 and Pl. I.)

OZARK MOUNTAIN REGION.

As has been said, the northeastern part of the state is the southwestern extension of the Ozark mountain uplift and the rocks are in general the same in character and relations as those exposed in the adjacent parts of Missouri and Arkansas. The area includes all or parts of Ottawa, Craig, Mayes, Delaware, Cherokee, Muskogee, Adair and Sequoyah counties.

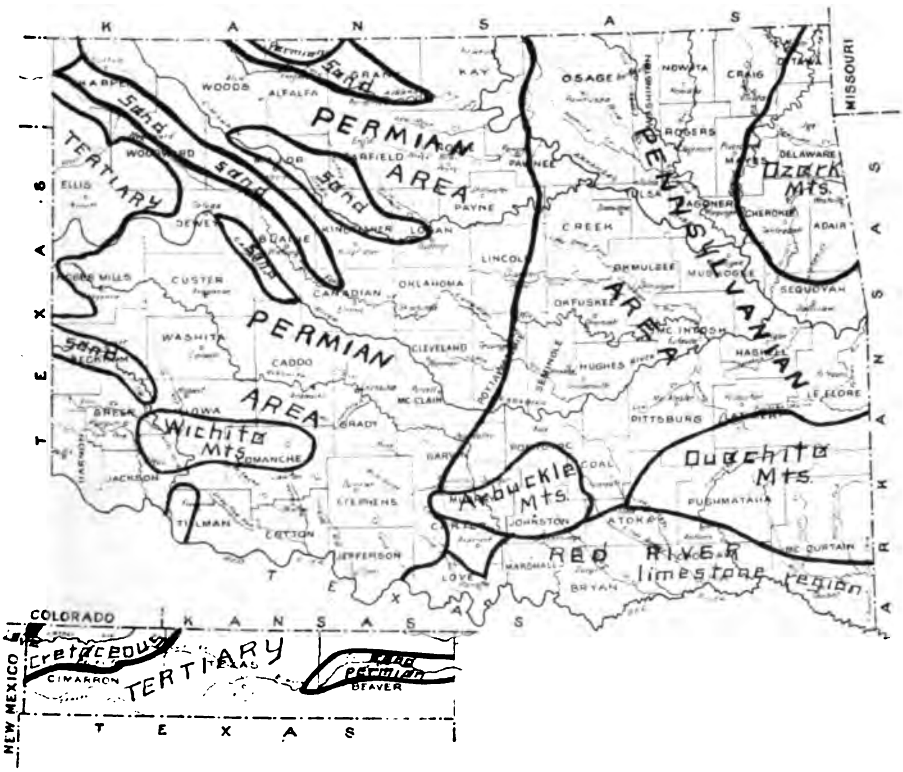

Fig. 52.—Sketch map of Oklahoma showing geologic areas.

The stratigraphy of the area is as follows:

ORDOVICIAN

(1) *Burgen sandstone*, white sacharroidal sandstone, 100 feet with the base not shown.

(2) *Tyner formation*, shales, sandstones and limestones usually greenish in color, 60 to 100 feet.

Unconformity.

SILURIAN

(3) *St. Clair marble,* white to gray or pink crystalline limestone, present only in southeastern part of area, at least 200 feet thick in northern Sequoyah county.

Unconformity.

DEVONIAN

(4) *Chattanooga shale,* black, slaty, bituminous shale, 66 to 40 feet.

Unconformity.

MISSISSIPPIAN

(5) *Boone formation,* limestone with cherts and flints, mostly of Burlington and Keokuk age, locally with Kinderhook beds at base, thickness from 100 to 400 feet.

Unconformity.

Batesville

(6) *Mayes formation,* dark shale with black, bituminous limestone in southern part of area; light, siliceous limestone in northern part, from 10 to 60 feet thick.

(7) *Fayetteville shale,* black, bituminous, clay shale with two or three beds limestone, absent in extreme north part of area up to 110 feet.

(8) *Pitkin limestone,* hard, generally well bedded, crystalline limestone, present only on south side of area, maximum thickness about 70 feet.

Of the formations named above, those below the Boone chert outcrop only in the deeper valleys in the eastern part of the region, while those above the Boone outcrop as a narrow fringe around the southern and western margin of the area. The Boone formation outcrops over approximately 90 per cent of the area.

In general the rocks dip to the south, southwest and west away from the Ozark uplift. The general structure, however, is much complicated by minor folding and by faulting.

PENNSYLVANIAN AREA.

This area occupies a broad L-shaped area on the south and west sides of the Ozark mountain region. The western limit is the Redbeds area, and the southern the Arbuckle and Ouachita mountains. Northward the area extends into Kansas and eastward into Arkansas. The area contains all or parts of the following counties: Ottawa, Craig, Nowata, Washington, Osage, Pawnee, Payne, Creek, Tulsa, Rogers, Mayes, Wagoner, Muskogee, Cherokee Sequoyah, Adair, LeFlore, Latimer, Haskell, Pittsburg, McIntosh, Hughes, Okmulgee, Okfuskee, Pontotoc, Seminole, Murray, Pottawatomie, and Lincoln.

The rocks of this area are shales, sandstones, and limestones of Pennsylvanian age. In the northern part of the area, north of Arkansas river, there are several limetsones, but these thin out and disappear to the south, and only two or three of them cross the river. To the south of the Arkansas practically all the rocks are sandstones and shales. These are much thicker than the rocks to the north of the river and present an entirely different section. It is necessary, then, to discuss the two portions of the area separately.

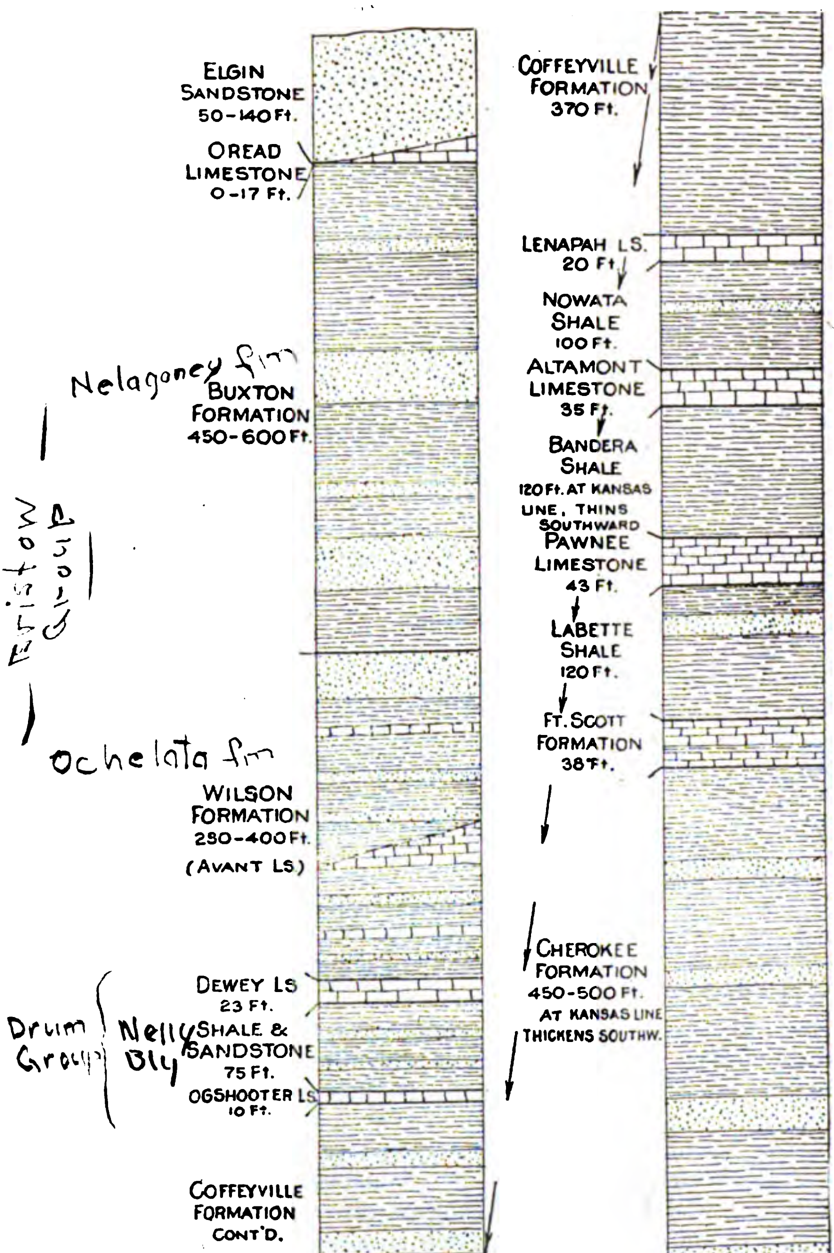

Fig. 53.—Columnar section of the Pennsylvanian rocks in northeastern Oklahoma (Prairie plains).

The Prairie Plains or Pennsylvanian Area North of Arkansas River.

General statement—The surface of this area slopes gently to the southeast. The alternation of hard and soft strata dipping gently to the west and northwest gives rise to a stairstep topography. The outcrops of the shales make broad flats or valleys, while the outcrops of the sandstones and limestones make pronounced eastward-facing ridges or escarpments. Going west each ridge or escarpment is slightly higher than the one to the east. The greater part of the drainage is into Arkansas river through the Verdigris and its branches. Since this area contains some of the most important oil and gas fields the nature and stratigraphy of the rocks are given rather fully. The columnar section is shown in fig. 53.

Stratigraphy—The formations exposed in this area with their descriptions are as follows, beginning with the lowest:

(1) The *Cherokee formation* consists of a group of shales, sandstones, limestone lenses, and coal beds. At the Kansas line the formation is less than 500 feet thick, but it thickens rapidly to the south and in the vicinity of Muskogee the rocks of the same horizon are included in two formations, the Winslow and Boggy which are together about 1,500 feet thick.

The outcrop is a belt of rather level land about 12 or 15 miles wide until it approaches the Arkansas, where it widens rapidly and extends eastward along the south side of the Ozark region. This formation is very important in the discussion of the oil and gas since it contains several of the important oil producing sands in the main field. The Bixler, Markham, Barnett, Bartlesville, and Burgess sands, named in descending order, lie in the formation. Of these the Bartlesville is of most importance. The heavy sandstone outcropping east of Welch, at Bluejacket, and northwest of Vinita is probably the Bartlesville. It has been recognized far to the westward beneath Osage county and to the southwestward in the oil fields of Tulsa, Creek, Pawnee and other counties.

(2) The *Fort Scott formation* consists of a lower limestone 10 feet thick separated by about 8 feet of shale from an upper limestone 20 feet thick. The whole thickness is thus 38 feet. The formation is known to the drillers as the "Oswego lime." In Oklahoma its outcrop forms a pronounced escarpment from the Kansas line, northwest of Welch in Craig county, southwest past Centralia, Chelsea, Claremore, and Catoosa to Arkansas river.

(3) Above the Fort Scott formation is a shale 120 feet thick known as the *Labette shale*. From Nowata northeastward a heavy sandstone occurs toward the top of the formation. It is not improbable that this is the outcrop of the so-called Holland sand which is productive of oil in the vicinity of Ochelata.

(4) The *Pawnee limestone* is about 40 feet thick. It outcrops along the west side of Verdigris river south from Nowata. At Talala the shale above the Pawnee pinches out and the Pawnee and the higher Altamont limestone unite to form the Oolagah which continues to the southward. The Pawnee and Altamont in the northern part of this area and the Oolagah in the southern part are known to the drillers as the "Big lime."

(5) The *Bandera shale* lies between the Pawnee and the Altamont limestones. At the Kansas line it is 120 feet thick, but it thins rapidly to the south until is only 40 feet thick at Nowata and disappears about Talala.

(6) The *Altamont limestone* is uniformly about 30 feet thick. It outcrops to the east of Nowata and southward along the Verdigris. South of Talala it unites with the Pawnee to form the Oolagah.

(7) The *Nowata shale* is about 100 feet thick at Nowata and thickens gradually to the south. A few thin sandstones are present in the formation, some of which are probably oil-bearing to the westward.

(8) The *Lenapah limestone* is about 20 feet thick at Lenapah and on the bluff in Nowata, but is not known to extend southward from that place. Its extension to the west under the younger formations is conjectural.

(9) The Coffeyville formation is composed principally of shales, but sandstones become prominent toward the south. The formation thickens from the Kansas line to the south, the average thickness being about 370 feet.

(10) The *Hogshooter limestone* is about 10 feet thick. It outcrops along Hogshooter creek about 9 miles east of Bartlesville. It is not usually recognizable in logs of wells to the west, possibly because it is thin bedded and is not noticed by the drillers and possibly because it does not extend far to the west.

(11) About 75 feet of unnamed shales and sandstones lie immediately above the Hogshooter limestone. The sandstones are thin and lenticular.

(12) The *Dewey limestone* is about 23 feet thick. It is well exposed in Bartlesville, near Dewey, and to the eastward and is prominent on the bluffs west of Ochelata and Ramona.

(13) The *Wilson formation* consists principally of shales with thin sandstone and limestone lenses. The principal sandstone lens is about 30 feet thick and lies about 100 feet below the top of the formation. It is well exposed at the village of Torpedo in the eastern part of Osage county. The principal limestone is exposed near Avant, and is known as the Avant limestone member.

(14) The *Buxton formation* of southern Kansas thickens southward into Oklahoma where in Osage county it embraces over 550 feet of sediments. A generalized section follows:

	Feet
Shale, sandy shale, and sandstone	140-155
Sandstone, exposed near Nelagony	50
Limestone, lentil	20
Shale, sandy shale, thin sandstones	100
Sandstone, exposed near Bigheart	140
Shale, and sandstone	180
Average total	630

The 50-foot sandstone of the above section is prominently exposed in the vicinity of Nelagony and is known to extend thence in both directions along the strike for a considerable distance. The limestone of the section is a lens and has but little linear extent.

The sandstone at the base of this section is really composed of several distinctive sandstones separated by shale beds. All the beds, however, are closely associated, especially at Bigheart, where they are well developed, several being thick and massive. They are known to extend from the eastern border of Osage county near Bartlesville southwest across this county and probably into Creek county.

(15) The *Oread limestone* overlies the Buxton formation in Kansas and extends 10 or 12 miles into Oklahoma where it pinches out. It is 17 feet thick at the Kansas line.

(16) The *Elgin sandstone* overlies the Oread or the Buxton where the Oread is absent. This sandstone extends southward across Osage county to Arkansas river where it caps the hills in the vicinity of Cleveland. Just south of the Kansas line near Elgin, Kans., the Elgin sandstone is 140 feet thick, and is made up of an upper and lower member, separated by shaly sandstone. To the southward the Elgin becomes thinner and consists usually of but a single member, which is in most places massive, containing practically no shale. From the central part of Osage county south to Arkansas river the Elgin is between 50 and 75 feet thick. The Elgin is equivalent to the upper part of the Kanwaka shale of Kansas.

The stratigraphic succession up to, and including the Elgin sandstone is shown in fig. 53.

The section above the Elgin sandstone is composed of very lenticular beds and no section can be given which will apply to any large area. There are, however, certain beds which are fairly persistent and which can be mapped for considerable distance along their outcrop. The following section is generalized from those given by K. C. Heald for the northwestern part of the Pawhuska quadrangle and for the Foraker quadrangle. (Bull. U. S. G. S. Nos. 641B, 1916, and 691B, 1918.)

(17) The *Pawhuska limestone* comprises a thickness of from 130 to 180 feet of limestones with intervening shales and some sandstone lenses. The limestone outcropping at Pawhuska is about the middle of the series. The topmost limestone is known in the field as the "red lime" on account of its rust-red color on weathered outcrops. The lowest limestone of the series is characterized by an abundance of horn corals (*Campophyllum torquium*) and is correlated with the Lecompton limestone of the Kansas section.

(18) Unnamed series of shales, sandy shales, sandstones and thin, lenticular limestones with a thickness of about 200 feet. The columnar section in the report on the Pawhuska quadrangle shows an unconformity in this series.

(19) The *Cryptozoon - bearing limestone*, is a characteristic bed of limestone 1 to 3 feet thick. It weathers to a dark gray color and is very hard and remarkably brittle. It contains large numbers of Cryptozoa, (indeterminate fossil forms) but other fossils are almost lacking.

(20) Unnamed series of shales, sandstones and thin limestones 70 to 80 feet thick.

(21) The *Stonebreaker limestone* is from 2 to 16 feet thick. It is a hard and tough limestone, light gray to dark blue in color, weathering to a dirty yellow, stained with limonite. The overlying shale contains numerous marine fossils particularly crinoid stems.

(22) Unnamed series of shales with thin limestones and sandstones, about 50 feet in thickness.

(23) *Sandstone B* (field designation) is a fairly definite and persistent bed of sandstone 1 to 8 feet thick. It

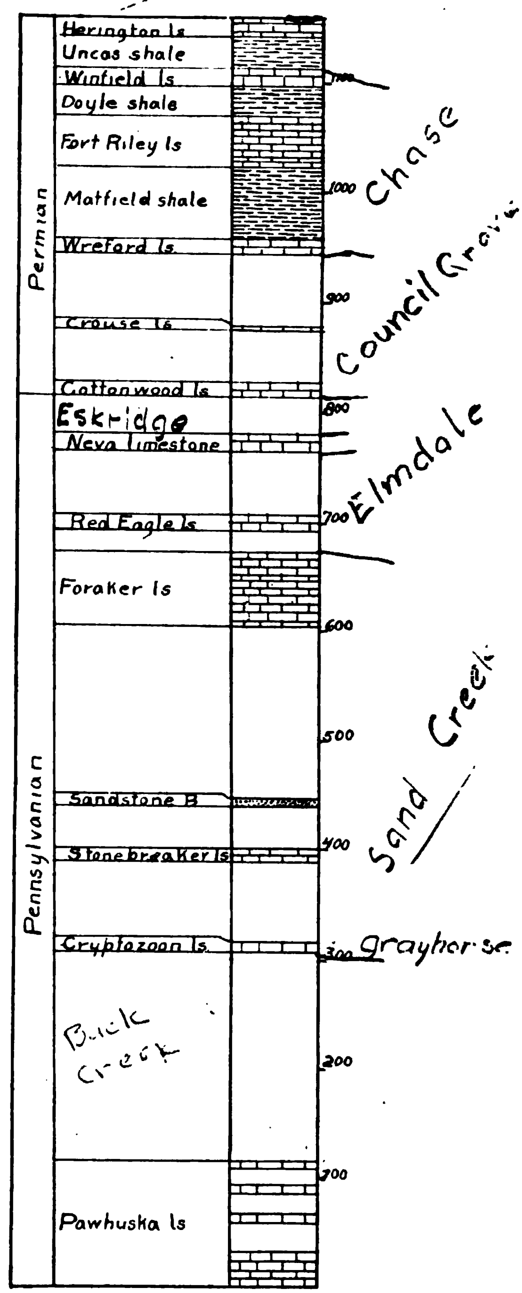

Fig. 54—Columnar section of the Pennsylvanian and Permian rocks in western Osage and eastern Kay counties.

is not strikingly different from other sandstones in the area but occurs in a considerable thickness of shale and is valuable as a "marker" bed.

(24) Unnamed series of shales with thin limestones, and minor sandstones about 150 feet in thickness.

(25) The *Foraker limestone* is about 70 feet thick and consists principally of soft, thin-bedded limestone with some shale layers. Chert concretions are abundant, and much of the lime stone contains large numbers of Fusulinas.

(26) Unnamed drab shale with thin limestone, about 20 feet thick.

(27) The *Red Eagle limestone* is in most places composed of alternating beds of limestone and shale with a total thickness of up to 17 feet. Locally the whole formation is composed of limestone.

(28) Unnamed series of thin, clayey limestones and calcareous shales, about 70 feet thick.

(29) *Neva limestone* is from 15 to 20 feet thick. It is made up of massive limestone beds at the base and top with thin limestones and clay beds in the middle.

(30) Unnamed red and gray shale with lenticular sandstone about 45 feet thick.

The columnar section of the Pennsylvanian rocks above the Elgin sandstone is shown in fig. 54.

PERMIAN ROCKS.

(31) The *Cottonwood limestone* is from 10 to 16 feet thick. It has a hard resistant layer, about 2 feet thick, at the top, with softer thin oolitic limestone beds and thin shales below. Locally, there is a limestone conglomerate at the base.

(32) Unnamed red and gray shale with thin limestones, about 50 feet in thickness.

(33) The *Crouse limestone* is about 3 feet thick and is characterized by its weathering into massive blocks, the general absence of recognizable fossils except small Fusulinas, and the abundance of smooth round holes which are vertical or steeply inclined to the bedding.

(34) Unnamed shale, with thin sandstone and limestone, about 70 feet thick.

(35) The *Wreford limestone* consists of three distinct limestone beds separated by shales. The limestones are very cherty and the middle bed has a characteristic buff color. The total thickness is from 10 to 14 feet.

Structure—The general structure of the Pennsylvanian rocks north of the Arkansas river is a monocline with a westward dip averaging 30 feet to the mile along the Kansas line. The rate of

dip further to the south is not known exactly, but does not seem to be greatly different. The general westward dip is often broken by gentle folds which give local east dips. In some cases the folding is so gentle that no eastward dip is observed, but the rocks lie nearly level for some distance and then dip to the west with a greater dip than the average. There is thus a smaller monocline or arrested anticline superimposed on the large one. Some of the anticlinal folds are so short as to be classed as domes. It should be emphasized that the structure in this area is very gentle except around the margin of the Ozark region. In some cases the dips are great enough to be observed with the eye or measured by a clinometer, but ordinarily, several elevations of a given ledge or horizon must be determined and the dip calculated from the difference in elevations. The streams cutting the rocks often give opportunities for these determinations. In many places detailed mapping and determination of as many elevations as possible by means of an alidade or transit is necessary before the structure can be made out. In some of the oil pools it is possible that there is no structure, but that the accumulation is due to short lenses of sand or local thickenings in the bodies of sandstone. The way in which these may effect the accumulation has been noticed in the section on theories of accumulation.

Sandstone Hills Region or Pennsylvanian Area South of Arkansas River.

General statement—The area of Pennsylvanian rocks south of the Arkansas differs from the area to the north principally in the almost complete absence of limestones and the greater abundance of sandstones which are much thicker than those to the north of the river. These sandstones give the region as a whole a very rough surface and the name, sandstone hills region, is more applicable to this portion of the Pennsylvanian area than to the northern portion.

Stratigraphy—While the rocks are the southern continuation of those north of the river they are so different that it was necessary for the United States Geological Survey to use an entirely different set of names in the coal fields of the Choctaw Nation which were studied several years ago. These names apply particularly to the southern part of the area under consideration, especially to the coal fields. There is consequently a large area in Okmulgee, Okfuskee, McIntosh, Hughes, Seminole, and Pottawatomie counties where very little geologic work has been done and where there is considerable doubt as to the exact stratigraphy of the rocks and as to the name to apply to them. From the small amount of work that has been done, however, it appears that the succession of rocks in this belt is in general the same as for the extreme southern part of the area, and also that there is a general thinning of the strata,

especially of the sandstones. The thickening from north to south takes place in practically all the rocks, but is especially pronounced in the case of the Cherokee formation. As has already been observed this formation, which is less than 500 feet thick at the Kansas line, is represented in the region of Muskogee by two formations, the Boggy and Winslow, which are together 1,500 feet thick. Farther south the Winslow—the lower of the two formations—thickens enormously and in the vicinity of McAlester and Coalgate is represented by several formations having a combined thickness of over 6,000 feet. The entire section of the McAlester-Coalgate region is shown graphically in fig. 55.

The formations are as follows, beginning at the bottom:

(1) The *Wapanucka limestone,* 100 feet thick, which forms the "limestone ridge" near Atoka and south and southeast of McAlester.

(2) The *Atoka formation,* 3,100 feet thick, consisting of clay shale, sandy shale, and sandstone, which is generally thin-bedded and friable.

(3) The *Hartshorne sandstone,* 150 feet thick, consisting of brown sandstone with local beds of shale. This formation outcrops as a low, wooded ridge near the outcrops of the lower workable coals.

(4) The *McAlester shale,* 1,800 to 2,000 feet thick, consisting of blue and black shale, and sandstone of varying thickness, interbedded with several veins of coal, two of which are workable.

(5) The *Savanna sandstone,* 1,000 feet thick, consisting of thick-bedded sandstone and shale. Outcrops as prominent ridges near Savanna and McAlester and to the north and east. Thins out and disappears to the northward.

(6) The *Boggy shale,* 2,000 to 2,600 feet thick, consists of shale, shaly sandstones, and brown sandstones with local, thin, siliceous limestone and coal near the base.

(7) The *Thurman sandstone* about 200 feet thick consisting of brown sandstone, shale and chert conglomerates.

(8) The *Stuart shale,* 90 to 280 feet thick, consisting of blue and black clay shale with some sandstones.

(9) The *Senora formation,* 140 to 485 feet thick, consisting of brown sandstone generally thick bedded.

All these formations up to and including the Senora are believed to represent the interval occupied by the Cherokee formation near the Kansas line.

(10) The *Wetumka shale,* 120 feet thick, consisting of clay shale above and sandy shale and thin sandstone below.

(11) The *Wewoka formation,* 700 feet thick, consisting of massive, brown friable sandstone, with interstratified soft, blue clay shale, and some limestone.

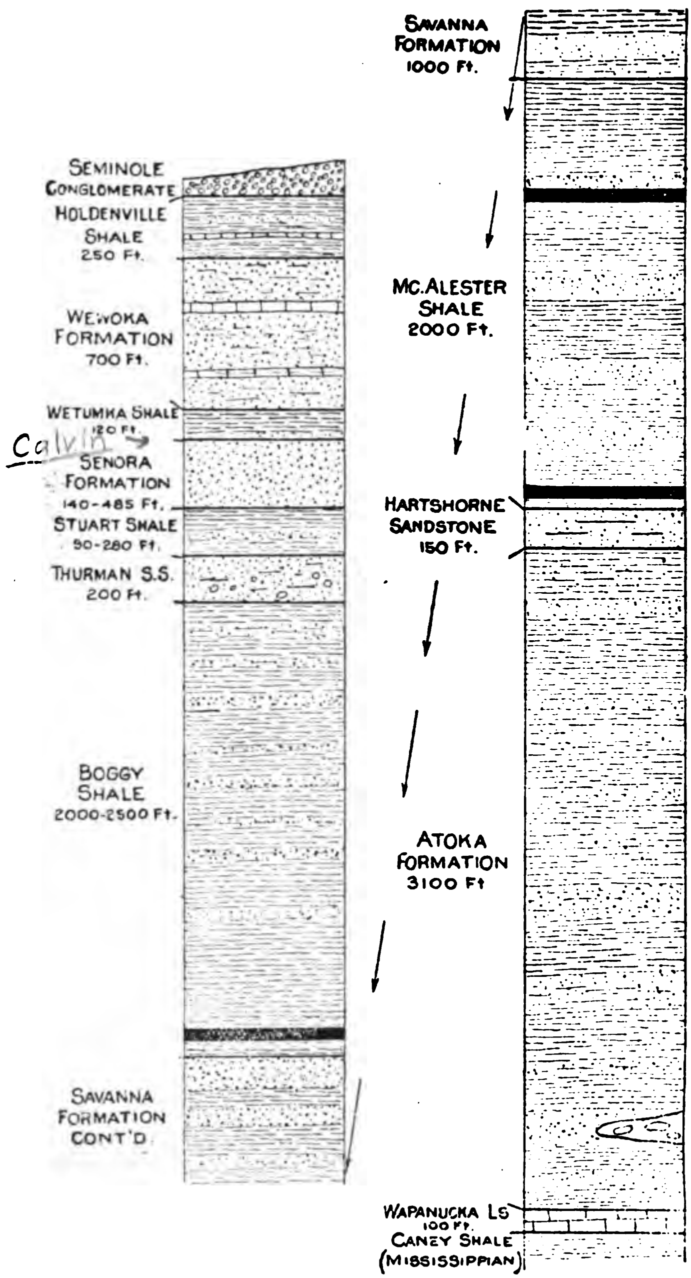

Fig. 55—Columnar section of the Pennsylvanian rocks south of Arkansas river. (Sandstone hills.)

(12) The *Holdenville shale,* 260 feet thick, consisting of blue and yellow clay shale with thin, siliceous limestone and sandstone beds.

(13) The *Seminole conglomerate,* 50 feet thick in the region studied, but thicker to the north, consisting of a conglomerate of white chert in brown sand, succeeded by brown sandstone.

Above these rocks and outcropping to the west are some higher unnamed shales and sandstones. These, however, can be considered as forming the lowest portion of the Redbeds since some of the members have the red color which becomes general a little higher in the section. It should be repeated that these formation names apply, as yet, only to the extreme southern portion of the area, but that they will probably be found to be applicable northwards almost to Arkansas river. At any event the rocks of the region between that worked out and the Arkansas consist of sandstones and shales, and it is thought that some, if not all, of the formations defined to the south have been recognized almost as far north as the Arkansas.

Structure—The structure of the portion of this area immediately south of the Arkansas is like that of the area north of the river, a monoclinal dip to the westward, interrupted occasionally by gentle folding. To the south, however, the folding becomes more intense and finally culminates in a very strongly folded and faulted area in the region to the north of the Ouachita mountains. The structure of the northern portion of the area has not been worked out, but that of the southern portion has been worked out in connection with the survey of the coal fields of the Choctaw nation. The principal folds of the coal fields have been described by J. A. Taff, in the nineteenth and twenty-first annual reports of the United States Geological Survey and by L. C. Snider in Bulletin, Oklahoma Geological Survey, No. 17.

OUACHITA MOUNTAIN REGION.

The Ouachita Mountain region occupies the extreme southeastern part of the state. The Ardmore branch of the Chicago, Rock Island & Pacific Railway forms the northwestern boundary; the main line of Missouri, Kansas & Texas Railway the western; the belt of level-lying Cretaceous rocks, the southern; and the State of Arkansas the eastern boundary of the area in Oklahoma. The area is continuous with a large area in Arkansas. In Oklahoma it occupies part of LeFlore, Latimer, Pittsburg, Atoka, Pushmataha and McCurtain counties.

Stratigraphy—A recent publication (Hugh D. Miser, Manganese deposits of the Caddo Gap and De Queen quadrangles, Arkansas; Bull. U. S. G. S. No. 660 C, 1917) on this area gives the following section for this region in Arkansas. All the beds down to

and including the Womble shale are known to cross into Oklahoma and the lower ones may also be present.

Beginning at the base:

CAMBRIAN

(1) *Collier shale*, bluish-black, soft, graphitic, intensely crumpled clay shale, some limestone and a few thin layers of dark chert, non-fossiliferous, 200 feet thick.

Unconformity.

ORDOVICIAN

(2) *Crystal Mountain sandstone*, coarse-grained, massive, gray to brown sandstone, calcareous in many places, 850 feet thick, provisionally assigned to the Ordovician.

(3) *Mazarn shale*, shale in alternating black and green layers with slaty cleavage, Lower Ordovician graptolites, 1,000 feet thick.

(4) *Blakely sandstone*, 0-400 feet thick in Arkansas, does not extend into Oklahoma.

(5) *Womble shale*, black, graphitic shale, with thin beds of sandstone near the base and beds of limestone near the top, contains numerous Lower Ordovician graptolites, thickness about 1,000 feet.

(6) *Bigfork chert*, thin-bedded, gray to black, much shattered chert with thin beds of black shale, fossils mainly graptolites, thickness about 700 feet.

(7) *Polk Creek shale*, black graphitic shale, in part siliceous; graptolites abundant; thickness 0 to 175 feet.

Unconformity.

SILURIAN

(8) *Blaylock sandstone*, probably limited above and below by unconformity, consists of fine-grained, light gray to dark gray or green compact sandstone and buff to dark shale; contains graptolites which correlate it with the basal Silurian of Scotland; thickness 0 to 1,500 feet.

(9) *Missouri Mountain* slate, red and green clay slate, no fossils, assigned to Silurian on lithologic and stratigraphic grounds; thickness 50 to 300 feet.

Unconformity.

DEVONIAN

(10) *Arkansas novaculite*, consists of three divisions—a lower one of massive, white novaculite, a middle one of thin layers of dense dark-colored novaculite, interbedded with shale, and an upper one of massive calcareous novaculite—contains some manganese in nodules and veins; fossils very scarce but the lower division is referred with some certainty to the Oriskany, and the middle and upper doubtfully to the middle upper Devonian; thickness, 250 to 950 feet.

Unconformity.

CARBONIFEROUS

(11) *Stanley shale*, dark colored, fissile, clay shale, and fine-grained compact, light-colored sandstone, separated from Arkansas novaculite by unconformity and has, locally, a conglomerate of novaculite fragments at the base; in western Arkansas and in Oklahoma has beds of gray-wacke near the base; thickness, about 6,000 feet.

(12) *Jackfork sandstone*, massive compact, fine-grained to coarse-grained sandstone with minor amounts of green, fissile, clay shale; thickness in Oklahoma about 4,000 feet.

The exact age of the Stanley and Jackfork formations is uncertain. The Arkansas novaculite is supposedly Devonian and the

Caney shale, which overlies the Jackfork sandstone in the western part of its outcrop, is late Mississippian in age. This makes the Stanley and Jackfork represent most or all of the Mississippian but the variation between this section and the Mississippian section in the Ozark mountain region a short distance to the north, and in the Arbuckle mountain region a short distance to the west, is remarkable.

Structure—The structure of the region is very complex. The rocks are very strongly folded and faulted and many of the folds are overturned.

Detailed geologic work has been done in a considerable part of the region by the United States Geological Survey, but the results have not been published and are not available. Nothing can be said, therefore, as to the exact location of the folds and faults. The structure, which causes all the rocks of the area to be strongly tilted, combined with the resistant properties of the thick Jackfork sandstone and Arkansas novaculite causes this region to have the roughest surface of any portion of the state. The hills are sufficiently high to be known as mountains and names have been given to some of the principal groups. Among these are the Jackfork, Kiamitia, Winding Stair, Pine, Potato Hill, and Williams mountains. Most of these mountains are formed by the Jackfork sandstone, but some of them are due to the Arkansas novaculite. Owing to its extremely rough surface the region has little agricultural land and is very thinly settled. Roads and transportation facilities are very poor.

ARBUCKLE MOUNTAIN REGION.

The Arbuckle mountain region is situated in the south-central part of the state. The uplift occupies parts of the following counties, Garvin, Murray, Carter, Johnston, Coal and Pontotoc. The rocks exposed range in age from pre-Cambrian to Pennsylvanian. The section is as follows, beginning at the base:

(1) The *Tishomingo granite* which forms the core of the mountains and outcrops in two areas, one east and one west of Washita river.

(2) The *Reagan sandstone,* from 0 to about 500 feet thick, composed largely of granite fragments with some shale in the upper portions, of Cambrian age.

(3) The *Arbuckle limestone,* 4,000 to 5,000 feet thick, composed almost entirely of thick and thin-bedded limestone of Cambro-Ordovician age.

(4) The *Simpson formation,* 1,200 to 2,000 feet thick, composed of sandstones, shales, and limestones of Ordovician age.

(5) The *Viola limestone,* 500 to 700 feet thick, composed of almost pure limestone of Ordovician age.

(6) The *Sylvan shale,* 60 to 300 feet thick, composed of green and black clay shales of Silurian age.

(7) The *Hunton limestone,* 0 to 300 feet thick, composed of two limestones and an intervening shale of Siluro-Devonian age.

(8) The *Woodford chert,* about 650 feet thick, composed of black shale with thin layers of chert, probably of Devonian age.

(9) The *Sycamore limestone,* 0 to 200 feet thick, composed of dense blue limestone, probably of Mississippian age.

(10) The *Caney shale,* about 1,600 feet thick, composed of black and blue shales of Mississippian age.

(11) The *Glenn formation,* of undetermined thickness, a complex of shales and sandstone of Pennsylvanian age, outcropping on the southern side of the mountains, especially in the Ardmore Basin.

(12) The *Franks conglomerate,* ranging from nothing to several hundred feet in thickness, composed of rounded pebbles and bowlders of limestone from the older rocks of the uplift. The conglomerate was deposited in Pennsylvanian times and lies unconformably on the up-turned edges of most of the older rocks.

History—The rocks composing the Arbuckle mountains were deposited in pre-Pennsylvanian times in water which varied in depth from time to time and portions of the area were above the water for comparatively short intervals. During Pennsylvanian times the area was uplifted into the shape of an immense dome. As soon as the uplift commenced, the forces of weathering began their work of tearing down the exposed rocks and transporting them back to the ocean. By the end of Pennsylvanian times probably as much as two miles thickness of material had been removed from above the granite core of the mountains. Toward the end of this period the sea again advanced over the area and the Franks conglomerate was built up from the bowlders of limestone which covered the old land surface. Later the lower parts of the Redbeds were deposited around the edges of the mountains probably a good deal higher than we find them now, since considerable thickness of them must have been removed by erosion since they were deposited. We have, then, in the Arbuckle mountains a truncated dome with the granite forming the core of the uplift and the steeply upturned older sedimentary rocks dipping in all directions away from it. Over the edges of the upturned rocks at some distance from the granite core we have the Franks conglomerate and the Redbeds.

Structure—The structure has been spoken of as a dome, but it must be understood that the structure is not as simple as the term indicates. The rocks were under great pressure, as the uplift was formed by thrusts from the sides and not by pressure from beneath As a result there were many minor folds produced and much faulting. Some of the folding is extremely complex and the faulting

is so general as to make the structure very difficult to work out. The areas of the principal folds have been worked out with some degree of accuracy, but on account of the faulting and other conditions the folds are almost certainly without effect on oil and gas accumulation and there is no need of considering them in detail in this work.

WICHITA MOUNTAIN REGION.

The Wichita mountains lie in the southwestern part of the state, in Comanche, Tillman, Jackson, Greer, and Kiowa counties. The long axis of the Wichita mountains is in line with that of the Arbuckle mountains and the two groups are almost certainly parts of the same general uplift with the connecting portion buried beneath the Redbeds between them. The Wichitas have had the same history and the same mode of formation as the Arbuckles, except that the Redbeds were deposited much higher relatively on the Wichitas and buried them so deeply that only the granite peaks and some of the higher limestone hills remained above the Redbeds or have been uncovered by erosion. Of the section of sedimentary rocks as exposed in the Arbuckles only the Reagan sandstone, Arbuckle limestone, and Viola limestone are shown in the Wichitas and these only in comparatively small areas on the north side of the mountains. The Wichitas, then, may be regarded in the same way as the Arbuckles—as a truncated dome exposing considerable areas of the granite in the core of the uplift, and with the level-lying Redbeds lapping up over the upturned edges of the older sedimentary rocks. Presumably these older sedimentaries are folded and faulted, similarly to those of the Arbuckles, but the covering of Redbeds completely hides the structure of the underlying rocks.

RED RIVER LIMESTONE REGION.

This area lies in the southern part of the state between Red river on the south and the Arbuckle and Ouachita mountains on the north. Parts of Love, Carter, Atoka, Pushmataha and McCurtain counties and all of Marshall, Bryan and Choctaw counties are included in the area. The rocks are sandstones, shales and limestones, which dip very gently to the southeast. The section as exposed is as follows, beginning at the base:

COMANCHEAN—

(1) The *Trinity sand,* 300 to 400 feet thick. Fine yellow sand with conglomerate beds locally at the base.

(2) The *Goodland limestone,* 25 feet thick, massive white limestone.

(3) The *Kiamichi formation,* 150 feet thick, blue soft shale with thin shell limestone beds in the lower portion.

(4) The *Caddo limestone,* 60 feet thick, yellow and white limestone interstratified with thin marly beds.

(5) The *Bokchito formation,* 140 feet thick, red and blue shale with thin irony limestone and lentils of soft sandstone.

(6) The *Bennington limestone,* 10 to 15 feet thick, blue shell limestone.

CRETACEOUS—

(7) The *Silo sandstone,* 200 feet thick with the top removed, brown, soft sandstone, locally hardened by iron cement, shale and shaly sandstone.

All these formations dip gently to the southeast. The Trinity sand laps over the upturned edges of the older rocks of the Arbuckle and Ouachita mountains to the north. The dip of the formations is in general very uniform but local structures of some magnitude have been found. The limestones are more resistant than the sandstones or shales and usually stand up as northward facing bluffs which extend for long distances east and west. Both the limestones and the limy shales form a very rich soil when weathered down.

PERMIAN REDBEDS AND TERTIARY REGION.

Lying above and outcropping to the west of the Pennsylvanian rocks is a great thickness of red shales and sandstones which are mostly of Permian age. In Kansas most of the Permian rocks are non-red and only the upper portion has the red color, but on coming south into Oklahoma the rocks of the lower part of the system begin to take on a red color and a short distance south of the state line all the Permian rocks and the extreme upper portion of the Pennsylvanian rocks are red. The only non-red Permian rocks in Oklahoma, except for some thin beds occurring with the red rocks, are in an area comprising most of Kay county and small portions of Osage and Pawnee counties adjoining Kay.

The Permian or Redbeds area occupies practically all the western half of the state, the eastern boundary being a line drawn from Blackwell southeast, passing east of Perry and Stillwater, past Chandler to Shawnee and thence southwest to the west end of the Arbuckle mountains, around the mountains and south to Red river. Included in the territory west of this line are the Wichita mountains, composed of older rocks, and some large areas in Ellis, Woodward, Harper, Beaver, Texas, and Cimarron counties, which are covered by rocks of Tertiary age much younger than the Redbeds. These rocks, however, are underlaid at a depth of at most a few hundred

feet by the Redbeds. As far as the prospects for oil and gas are concerned the area may be considered as part of the Redbeds area.

The Redbeds consist of a great, but not definitely known, thickness of soft, red sandstones and shales with some ledges of gypsum and thin ledges of dolomite. The lower limit of the beds is not a plane since the rocks lower and lower in the series take on a red color to the south of the state line. The thickness is much greater therefore in the latitude of Shawnee than it is along the Kansas line and the beds thin again to the south in the vicinity of the Arbuckle and Wichita mountains. Near the middle of the state the beds probably reach a thickness of over 3,000 feet.

Stratigraphy—The Permian Redbeds in Oklahoma are subdivided as follows, from the base up:

(1) *Enid formation,* principally soft red clay and sandy clay shales with lenticular red sands and some thin beds of white sand, about 1,500 feet thick.

(2) *Blaine formation,* consisting of three gypsum members—the Ferguson, Medicine Lodge and Shimer—with intervening red and green shales, about 100 feet thick.

(3) *Woodward formation,* consisting of the Dog Creek shale member, Whitehorse sandstone member, and Day Creek dolomite member, total thickness about 425 feet.

(4) *Greer formation,* consisting of the Chaney, Kiser, Haystack, Cedar Top, and Collingsworth gypsum members, the Mangum dolomite member and intervening red and green shales.

(5) *Quartermaster formation,* consisting of soft red sandstones and arenaceous clays and shales, about 300 feet thick.

The erratic nature of the stratigraphy of the Redbeds, the softness of the rocks, and the cross-bedding of the sandstones, which, besides the gypsums, are the only ledges which can be traced for any considerable distance, makes it very difficult to determine any minor structures in the Redbeds but from all indications there are no structures in the greater part of the area which would be favorable for the accumulation of oil or gas. In the vicinity of the Arbuckle and Wichita mountains and in the belt between these mountains and Red River folds have been found, at least some of which are connected with the accumulation of oil and gas. The eastern portion of the region has also shown favorable structures when worked carefully. Too much emphasis cannot be given the fact that little reliance can be placed on appearance of structure in short outcrops in this region. The cross-bedding of the sandstones is extreme and in short exposures gives all the appearance of strong dips, but when the ledge as a whole can be followed any distance it proves to be practically level in most cases. The shales associated with the sandstones are very soft, and when wet work out from under the sandstones permitting the latter to slip. Large pieces are often

broken from the ledges and lie in positions which indicate strong dip. In most cases, however, this condition can be made out and the ledge in place is found to be level. These conditions of cross-bedding and slip occur so often where they can be definitely identified as such that it is only fair to presume that appearances of dip in very short exposures of single ledges are due to one of these causes unless they can be shown conclusively to be real dips.

So far, the only pools of importance in the Redbeds region, outside of the Wichita-Arbuckle mountain area, are those at Billings, and Garber and in these localities the Redbeds are sufficiently thin to permit the underlying non-Redbeds to be reached. The structure is shown by persistent sandstone beds.

Much of western portion of Oklahoma is covered with a thin mantle of Tertiary sands and clays. These prevent a determination of the structure of the underlying rocks. There are also small, isolated patches of Comanchean limestone, the remnants of a formation which undoubtedly covered the whole area at one time, and connected the Comanchean areas of Kansas and Texas. The Dakota sandstone occupies a small area in the Panhandle but the other Cretaceous formations, which have been described for Kansas, do not outcrop in Oklahoma.

GEOLOGY OF TEXAS.

For convenience of discussion of the geology, Texas may be divided into eight regions as follows:

(1) Llano-Burnet uplift or central mineral region.
(2) North-central plains or Pennsylvanian-Permian region.
(3) High plains.
(4) Cordilleran region.
(5) Toyah basin.
(6) Edwards plateau.
(7) Black and Grand prairies.
(8) Gulf Coastal plain.

The regions are shown on the accompanying sketch map (fig 56) and in Pl. II.

Each of the areas is described briefly in the following paragraphs.

LLANO-BURNET UPLIFT.

The Llano-Burnet uplift brings to the surface the oldest rocks exposed in Texas. Its topographic expression is a low basin from which Colorado river and its tributaries have removed the covering of Comanchean rocks exposing the older rocks beneath. While considerably lower than the plains to the north, south and west, the region is well dissected and the surface is quite hilly.

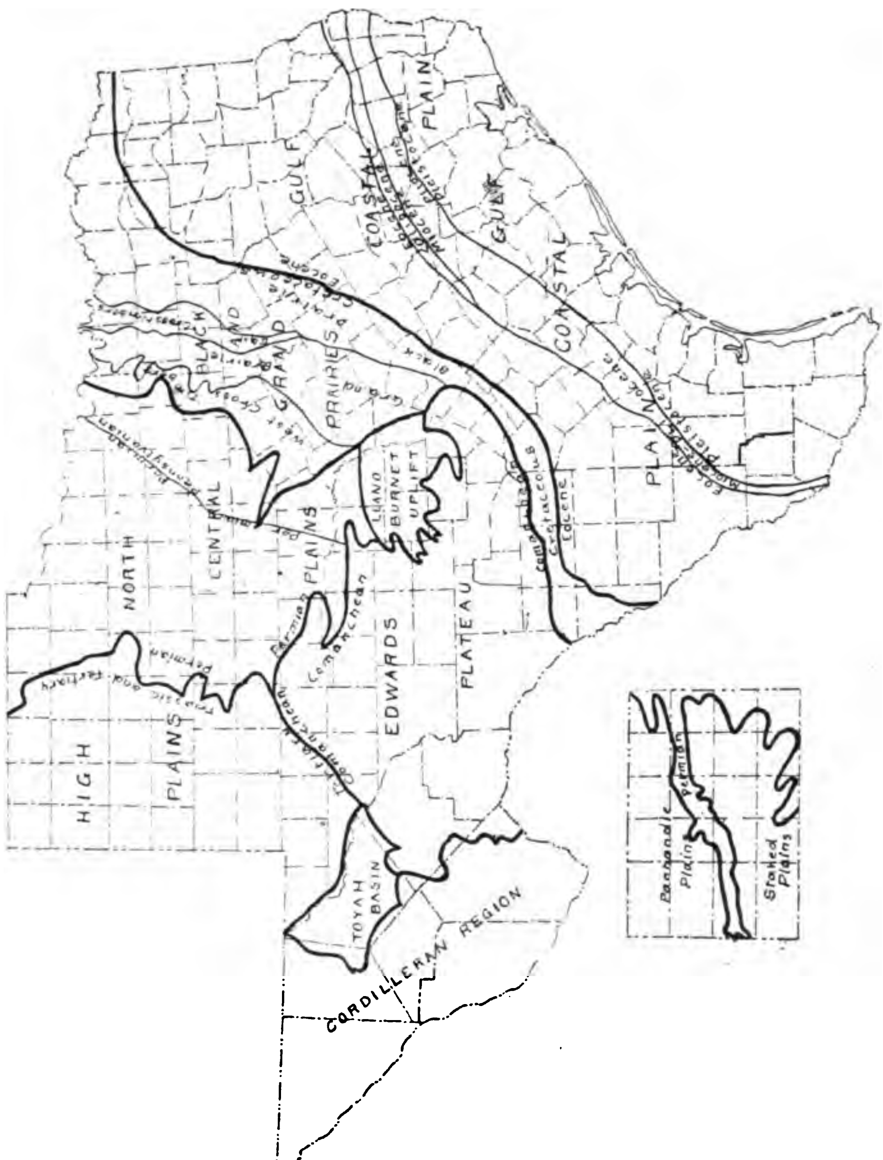

Fig. 56.—Sketch map of Texas showing geologic provinces.

The area includes all of Llano, practically all of Mason and parts of Burnet, Blanco, Gillespie, Kimble, McCulloch, San Saba, and Lampasas counties. The stratigraphic succession of the rocks exposed in the uplift is as follows:

Pennsylvanian System
- Bend series.
  - Smithwick shale
  - Marble Falls limestone
  - Lower Bend shale

Unconformity.

Cambro-Ordovician
- Ellenberger limestone

Cambrian
- Wilberns formation
- Cap Mountain formation
- Hickory sandstone

Unconformity

Pre-Cambrian
- Intrusive granite
- Valley Spring gneiss
- Packsaddle schist.

PRE-CAMBRIAN ROCKS.

The *Packsaddle schist* and *Valley Spring gneiss* include a great thickness of very highly metamorphosed sedimentary and igneous rocks, presumably of Algonkian age. The schist is generally dark in color and has well developed cleavage planes; the gneiss is lighter in color and with less pronounced cleavage. The two formations, however, grade into each other, and, in many places are very difficult of separation. The schist contains beds of marmorized limestone, and also graphitic beds, which make its origin from sedimentary beds beyond question. Both the schist and the gneiss are intruded by large masses of granite and by smaller dikes of basic rocks. The intrusives are also presumably of pre-Cambrian age. Graphite, magnetite, galena, fluorite, copper, manganese and zinc occur in some quantity and the rare earth minerals are mined at Barringer Hill in Llano county.

CAMBRIAN SYSTEM.

Hickory sandstone overlies all the pre-Cambrian rocks in the region. It consists of sandstone with a basal conglomerate. Locally the sandstone is highly ferruginous and strikingly red in color. The formation grades upward into the Cap Mountain formation. The thickness of the Hickory varies from a few feet to 350 feet.

Cap Mountain formation consists of limestone and sandstone, both more or less glauconitic. The thickness is about 90 feet.

Wilberns formation consists principally of thin-bedded limestones with shale in the upper portion. The maximum thickness is 220 feet.

CAMBRO-ORDOVICIAN ROCKS.

Ellenberger limestone consists of crystalline, dolomitic, light-colored limestone, containing much white and yellow chert. The upper portion is of purer limestone than the lower. The total thickness is about 1,000 feet.

PENNSYLVANIAN SYSTEM.

The Pennsylvanian rocks of this region have been grouped as the Bend series. At the base, locally, is about 50 feet of black fissile evenly-bedded, bituminous shale.

Marble Falls limestone consists of light gray to black well-bedded limestone with considerable dark blue to black chert. Thin shale partings are common but the limestone predominates very greatly. The thickness at the outcrops is about 450 feet. The age of the Marble Falls has been variously considered, but it is now regarded as being Pennsylvanian, of about the same horizon as the Morrow group of Arkansas and northeastern Oklahoma and of the Wapanucka limestone and Caney shale of east-central Oklahoma. The formation outcrops in isolated areas, on the outer fringe of the Ellenberger limestone outcrop on the eastern and northern side of the uplift. On the southern and western sides, the Marble Falls, if present, is covered by the Comanchean. The Marble Falls limestone is of extreme interest on account of its being the source of the oil and gas in the Ranger and the Stephens county fields. Its extent to the north is noted in the description of the Pennsylvanian-Permian area. Concerning its extension to the south and west of the uplift nothing definite can be said but there is no apparent reason why it should not extend for considerable distances to the south and west. The Marble Falls has been affected by all the folding of the Llano-Burnet uplift and was undoubtedly deposited over the entire area of the uplift. The location of the land mass from which its sediments were derived is problematic but was probably to the southeast, so that the extension of the formation to the southeast is doubtful and, at any rate, its horizon is so deeply buried under Cretaceous rocks within a very short distance that it is out of reach of drill.

Smithwick shale consists of black, bituminous and carbonaceous shale about 400 feet thick, with some sandstone lentils. It is apparently conformable with the Marble Falls and outcrops in the same localities.

NORTH-CENTRAL PLAINS.

(Pennsylvanian-Permian)

The area of Pennsylvanian and Permian rocks lies in the north-central part of the state, coinciding with the physiographic province known as the north-central plains. It is the southward continuation of the Pennsylvanian-Permian areas of Kansas and Oklahoma. In Texas it includes all or part of the following counties: Montague, Clay, Jack, Wise, Parker, Palo Pinto, Stephens, Eastland, Comanche, Brown, San Saba, Mills, McCulloch, Coleman, Concho, Tom Green Runnels, Callahan, Taylor, Shackelford, Jones, Haskell, Throckmorton, Young, Archer, Baylor, Knox, Foard, Wichita, Wilbarger, Hardeman, Lipscomb, Hemphill, Wheeler, Collingsworth, Donley, Briscoe, Hall, Childress, Motley, Cottle, King, Dickens, Garza, Kent, Stonewall, Borden, Scurry, Fisher, Mitchell, Nolan and Coke, with a narrow belt along the Canadian river in Roberts, Hutchinson, Moore, Potter and Oldham.

The rocks of the Pennsylvanian-Permian area in north-central Texas have been subdivided as follows:

Permian
- Double Mountain formation
- Clear Fork formation
- Wichita-Albany formation

Pennsylvanian
- Cisco formation
- Canyon formation
- Strawn formation
- Bend series
  - Smithwick shale
  - Marble Falls limestone

PENNSYLVANIAN SYSTEM.

The character and thickness of the *Marble Falls limestone* and the *Smithwick shale*, which form the Bend series, has been noted in connection with the description of the Llano-Burnet area where they outcrop. These formations extend northward and northwestward for a considerable distance under the younger formations. In the area under consideration they are of immense importance since the Bend series acts as the reservoir for the oil and gas in the fields in Eastland and Stephens counties. Judging from the well-logs there is no pronounced variation in the thickness of these beds, northward from the Llano-Burnet mountains through Brown, Coleman, Comanche, Eastland and into Stephens county, but both formations are more sandy to the northward. To the north and east the exact correlation of the "Black lime" (Marble Falls limestone) is more uncertain. Nothing which could be definitely correlated with

the Marble Falls was encountered in the Chestnut well of the Empire Gas & Fuel company south of Mineral Wells, which was drilled to a depth of about 4,200 feet. In the Lyle well in southeastern Young county a formation was encountered which was thought to be "Black lime."

Strawn Formation.

This formation is exposed in two regions separated from each other by the overlapping Comanchean rocks, which everywhere, except along the northern edge of the Llano-Burnet mountains, conceal the base of the formation.

In the southern area in Brown, San Saba, Mills and Lampasas counties, the whole formation consists of alternating beds of hard, evenly textured sandstones and blue clay shales, with some conglomerates and a few thin, hard limestones. Along Colorado river, Drake in his report on the Colorado Coal Field of Texas (Fourth Annual Report of the Geological Survey of Texas) divides the Strawn into twenty distinct beds, with a total thickness of more than 4,000 feet. These beds are shown in the columnar section (fig. 57.)

In the northern area, in Wise, Jack, Parker, Palo Pinto, Erath and Eastland counties, the Strawn is divided into two divisions: a lower, formerly called the Millsap beds, composed of blue to black clay shale with only a little sandstone and a few thin limestones, and an upper of alternating sandstone and shale with a few thin limestones. The base of the Strawn is not exposed in this area so the total thickness at the outcrop is not known.

The Strawn seems to have been deposited in a narrow gulf or embayment extending from the north to or beyond the Llano-Burnet region. This embayment transgressed westward during Strawn and later Pennsylvanian times so that the upper part of the Strawn and the overlying formations were deposited farther to the west than the basal part of the Strawn. This is shown by the progressive westward overlapping of the higher beds upon the Bend series along the northern margin of the Llano-Burnet uplift. From east to west the Bend is overlain successively by the Strawn, the Canyon and probably by the Cisco and lowermost Permian beds. A corresponding change is shown by well records farther north. While the thickness at the outcrops is in the neighborhood of 4,000 feet, not more than 1,000 feet of Strawn formation is shown in well logs only 15 or 20 miles to the west. In the Russell well near the southern end of the Coleman-Runnels county line the Strawn does not seem to be present, and the drill passed directly from the Canyon formation into the Bend series.

The Strawn formation is the source of the oil and gas in the Strawn field and has produced small amounts of both substances at

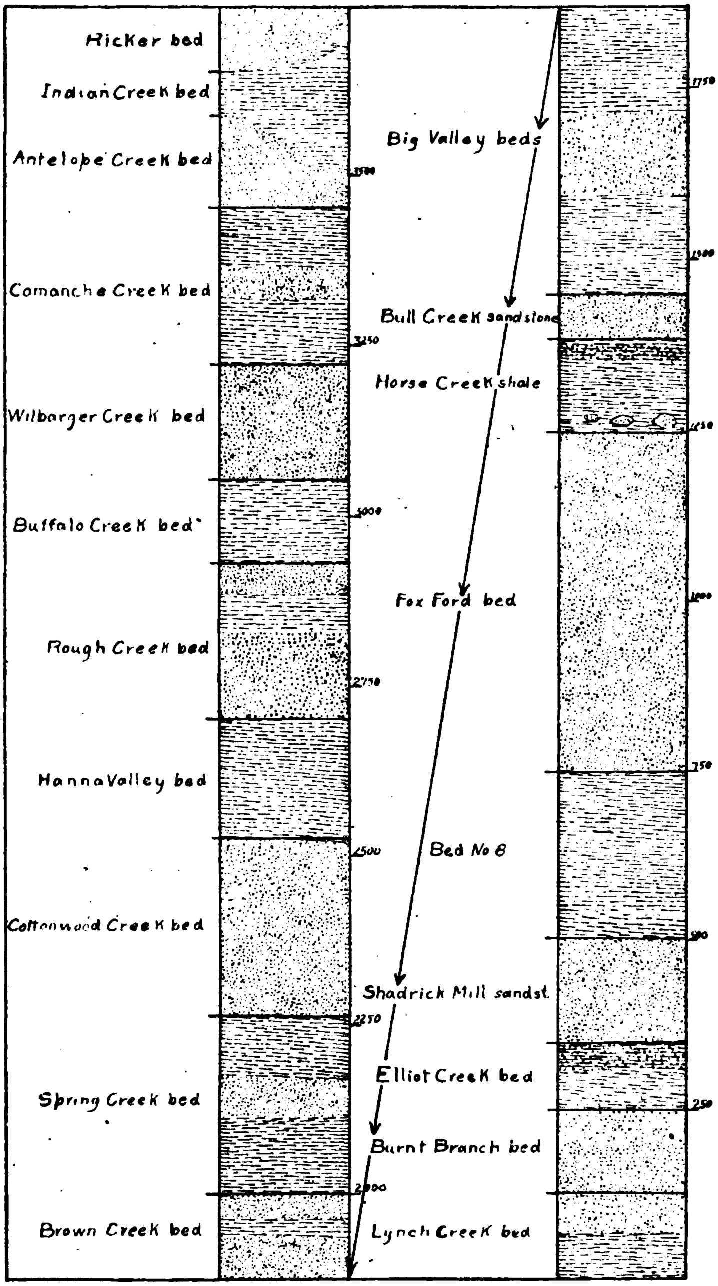

Fig. 57.—Columnar section of the Strawn formation in the Colorado river region.

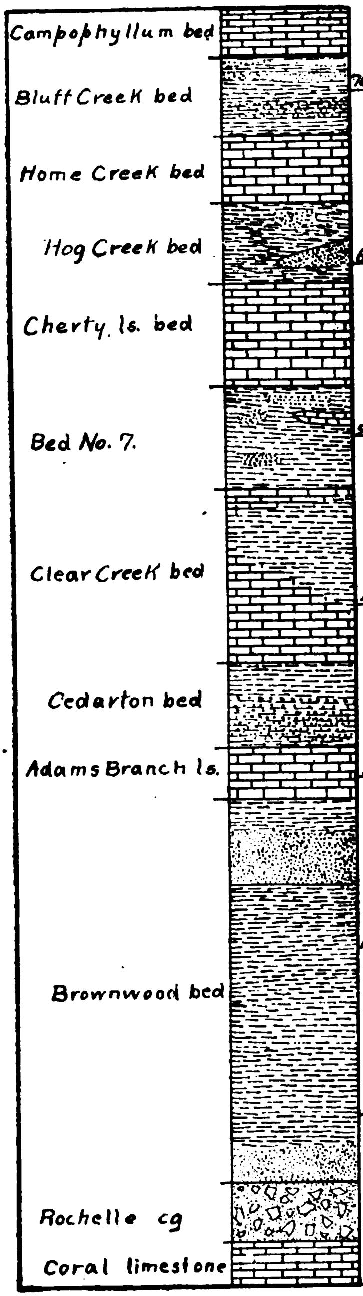

Fig. 58—Columnar section of the Canyon formation in the Colorado river region.

several other localities. Several beds of coal occur in the formation and coal is mined on a large scale from these beds at Strawn, Mingus, Thurber and Bridgeport.

Canyon Formation.

This formation succeeds the Strawn conformably, but in its westward extension probably rests unconformably on the Bend series, on account of the pinching out of the Strawn formation.

The formation consists of alternating beds of bluish-gray limestone and blue clay with minor amounts of conglomerate and reddish sandstone.

Along Colorado river, Drake (op. cit.) divides the formation into twelve beds which may be traced for some distance north into Brown and Coleman counties. The columnar section for this region is shown in fig. 58. In this region the limestone beds are none of them over 30 feet in thickness. To the north some of these limestones thicken and probably coalesce by the pinching out of the intervening shales until in Palo Pinto and Jack counties, there are four principal limestone beds. The individual beds in this region reach a thickness of at least 50 feet. These limestones are particularly well shown in Metcalf gap and on the road, between Palo Pinto and Breckenridge. Northward from Jack county the limestones thin and the clays are more prominent and there is more sandstone, especially in the lower part of the formation.

Cisco Formation.

This formation overlies the Canyon conformably. The formation

is composed of typical blue clay shales, intercalated with beds of sandstones, conglomerate, with a few thin beds of hard limestones. The limestones are thicker and more numerous in the southern part of the outcrop near the Llano-Burnet uplift. Along the Colorado river, Drake (op. cit.) has mapped and named eighteen subdivisions, (fig. 59) but it is not known how far northward these beds maintain their individuality. In the northern part of Young and Jack counties the limestones disappear from the section. Beginning in Stephens county there is a gradual change in the color of the shales and sandstones from blue and gray to red, until along Red river in Clay and Montague counties the formation is represented principally by Redbeds and has not been separated from the overlying Wichita formation.

The thickness of the Cisco averages about 800 feet. The precise thickness in the northern part of its outcrop is not known on account of the difficulty of separating the Cisco from the Wichita formation.

* * * * * * * * * *

The Canyon and Cisco formations are extremely important in geologic work in North Texas. The following brief discussion of the stratigraphy of these formations and the sections (fig. 59) are kindly furnished by F. B. Plummer of the Roxana Petroleum company.

NORTH TEXAS PENNSYLVANIAN FORMATIONS.

The area of outcrop of the Pennsylvanian rocks in north Texas is a narrow belt extending from San Saba river on the south to Red River on the north. The average width of the outcrop is about 50 miles, and the total area is about 7,000 square miles included mostly in Jack, Young, Stephens, Palo Pinto, Eastland, Coleman, Brown, McCullough and San Saba counties.

Prof. W. F. Cummins (2nd Ann. Report, Geol. Survey of Texas, page 359) first described the Pennsylvanian of north Texas and divided it into three divisions, as follows:

3.—Cisco.
2.—Canyon.
1.—Strawn.

The Cisco division is composed of soft sandstones, calcareous shales, and thin yellow-brown fossiliferous limestones, and contains the Waldrip coal seam. This series of beds has a total thickness of approximately 1,000 feet.

The Canyon division is made up of massive, hard, thick, blue limestones and gray and blue marl and shale. It has an average thickness of 800 feet.

The Strawn division is made up of thick, massive, poorly bedded sandstone, conglomerate, sandy shales, and a few lenticular dark-

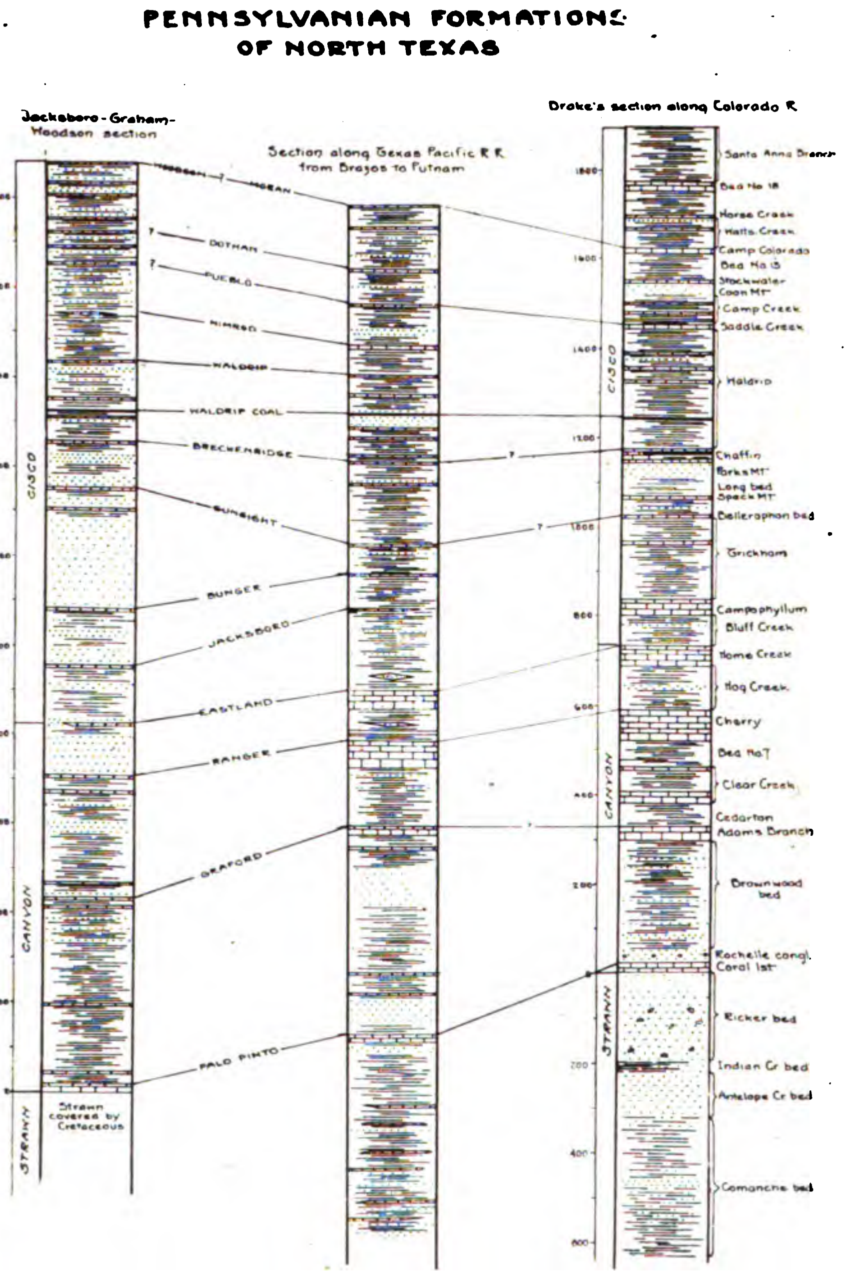

Fig. 59—Columnar section of the Canyon and Cisco formations in North Texas.

blue limestones. It contains the Strawn coal seam and has a measured thickness along its eastern outcrop of over 3,000 feet; it thins westward so that where penetrated by the drill at Moran it is less than 2,000 feet.

Drake a little later studied in detail the section along the Colorado river (see "The Colorado Coal Field"); Fourth Annual Report, Geological Survey of Texas, and subdivided the three divisions into separate beds as shown in the accompanying section. (fig. 59.)

The Geologists of Roxana Petroleum company have recently mapped all the Pennsylvanian formations north of the Colorado river (Bull. Am. Assoc. Pet. Geol. March, 1919), and have given names to all the limestones that can be traced continuously across the area of outcrop. The most prominent, continuous and recognizable limestones are as follows:

CISCO	Moran, (Lime of the Moran Oil Field.) Pueblo, (Lime west of Caddo.) Waldrip, (Lime above the coal seams at Cisco and Newcastle.) Breckenridge, (Lime in the town of Breckenridge.) Gunsight, (The fossiliferous lime at Gunsight.)
CANYON	Eastland, (Lime of the Caddo Oil Field.) Ranger, (Lime of the Ranger Oil Field.) Graford, (Lime forming the scarp west of Graford.) Palo Pinto, (Lime at the town of Palo Pinto.)

These lines are not only easily recognizable in the field, but are readily differentiated in the well logs so that they are of much help to the petroleum geologist in surface mapping and correlating well logs.

All the Pennsylvanian strata dip westward in the southern portion of their outcrop, and northwestward in the northern portions at an average rate of 50 feet per mile. In general the entire section thickens toward the northeast and thins toward the south and west. Thus in Jack and Young counties there are fewer limestones and thicker and more numerous layers of coarse sand and conglomerate than in Brown and Coleman counties to the south. To the west where penetrated by the drill beneath the Permian the section is much thinner and more calcareous, and shales and limes predominate.

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PERMIAN ROCKS.

Wichita-Albany Formation.

In the southern part of its outcrop this formation consists of gray to blue shales and hard, compact, massively bedded limestone. In this area the formation was originally described and named the

the Albany formation.* These rocks outcrop in a broad belt in Coleman, Concho, Runnels, Callahan, Taylor, Shackelford, Throckmorton and Young counties. Northward from Throckmorton and Young counties the marine limestones and clays grade rapidly into typical Redbeds, which were previously described as the Wichita formation. Near Red river the formation is not readily separated from the Cisco below, nor the Clear Fork above. The Wichita outcrops in Clay, Wichita, Wilbarger, Archer, Young and Throckmorton counties.

Clear Fork Formation.

This formation consists of red and blue clays, thin limestones, which are commonly dolomitic, white and red sandstones and some gypsum. The bedding is very irregular. The thickness is about 1,900 feet.

Double Mountain Formation.

The Double Mountain formation comprises about 2,000 feet of Redbeds. Except for containing thicker beds of gypsum and beds of rock salt it is very similar to the Clear Fork and the two formations grade into each other without any distinct break. In their extension to the south and west both the Double Mountain and Clear Fork formations seem to be replaced by limestones and thick beds of gypsum. The Double Mountain formation is equivalent to the Greer and Quartermaster formations in Oklahoma.

YOUNGER ROCKS IN THE PENNSYLVANIAN-PERMIAN AREA.

The lower beds of the Comanchean formerly covered the greater part, if not all, of the north-central area and many outliers and "stringers" from the main body to the south and east are found over the surface of the area. One re-entrant of the Comanchean cuts entirely across the outcrop of the Pennsylvanian along Pecan Bayou in northern Brown and southern Eastland counties, separating the Pennsylvanian outcrop into a northern and southern division.

In the northern part of the region, considerable areas of late Tertiary or Pleistocene sands and gravels, which have been mapped and described by Gordon† as the Seymour gravels, are deposited over the Permian beds. Farther southeast a peculiar conglomerate, composed of vari-colored quartz pebbles in a quartzitic matrix, occurs in many places in the hills. The writer believes this is of Tertiary or

*The stratigraphy of the Albany beds in the vicinity of Colorado river is fully described by J. W. Beede in "The Geology of Runnels County," University of Texas Bull. No. 1816, 1918.

†Gordon, C. H., Geology and Underground Waters of the Wichita region, north-central Texas; W. S. Paper U. S. Geol. Survey No. 317, 1913.

Pleistocene age and probably the extension of the Seymour gravels. Some gravels from the Comanchean beds are also residual on the hills.

The reworked gravels from these conglomerates and from those of the Cisco or Strawn formations, occur at different levels along the larger stream valleys and may easily be mistaken for the conglomerates interbedded in the Cisco and Strawn formations. In general, conglomerates should be used with extreme care in determining the structure of the region.

Another type of deposit which is confusing to one unacquainted to the region is known as "Caliche." This is a calcareous deposit formed by the evaporation at the surface of lime-bearing waters. In the semi-arid regions, the water is drawn from considerable depths by the capillarity of the rocks and on evaporating at the surface leaves a calcareous deposit cementing the soil into a firm mass, or even building up a nearly pure deposit of calcium carbonate, which may reach a thickness of several feet. "Caliche" may present the appearance of a bedded rock and so lead to error in determining structure. "Caliche" occurs to some extent over the southern and southwestern part of the Pennsylvanian-Permian region but is more abundant farther to the south and west.

HIGH PLAINS REGION.

The High Plains region in Texas includes the extreme western and northwestern part of the state. It embraces all of the counties west and northwest of an irregular line drawn from the northeast corner of the Panhandle slightly west of south to Howard county, thence southwest to Pecos river in Crane county, and thence northwest along the Pecos to the New Mexico line in Loving county.

Physiographically the High Plains region is a plateau of generally smooth, monotonous surface but broken by many deep, steep-sided canyons. The High Plains of Texas are the southward continuation of the Great Plains, which stretch along the eastern side of the Rocky mountains. In Texas the valley of Canadian river separates the Plains into two divisions, the Panhandle High Plains to the north and the Llano Estacado or Staked Plains to the south. The southern boundary of the High Plains is the valley of Pecos river. The eastern boundary is a high, precipitous escarpment formed by a limestone (caliche) locally known as the "cap rock."

The surficial rocks of the High Plains are continental deposits of late Tertiary and Quaternary age, which are underlain by Triassic beds, some remnants of Comanchean rocks, and the Permian beds previously described.

The Tertiary and Cenozoic rocks are derived from the Rocky mountains and thin to the east. They are so irregularly bedded and

so unconsolidated that they give no clue to the structure of the underlying rocks.

The structure of the Permian beds is a broad syncline with the deepest part under the High Plains. Several minor folds are known in the Permian rocks. The stratigraphy of the High Plains is discussed briefly in the following paragraphs.

TRIASSIC ROCKS.

Dockum beds—The Dockum beds, named and described by Drake, outcrop in a belt under the "cap rock" along the eastern escarpment of the High Plains. The beds consist of sandstone, and sandy clay. The individual beds are lenticular and cross-bedded. The prevailing color is red but there is much variation and the sandstones are locally gray or brown in color, while maroon, white, lavender and yellow shades are common in the clays. Although the Triassic beds resemble the underlying Permian Redbeds, the characteristics given above serve to differentiate the two systems. Silicified and lignitized wood and reptilian remains have been found which show the age of the Dockum beds to be late Triassic corresponding to the Keuper of Europe.

TERTIARY ROCKS.

Rocks of Tertiary age occur over most of the High Plains region but in most places form only a thin mantle and are generally less than 100 feet in thickness. The rocks are mostly of Miocene and Pliocene age. Some of the deposits have received distinctive names such as the Panhandle beds of middle and early Miocene age, the Clarendon, Loup Fork or Goodnight beds of the late Miocene and the Blanco beds of the middle Miocene.

PLEISTOCENE (AND PLIOCENE?) ROCKS.

Over the greater part of the High Plains, it spread a deposit of sands, gravels and clays of Pleistocene (probably in part Pliocene) age. The beds, as a whole, are composed of material of the same character over the whole region, but the individual beds are of small extent and detailed sections show great variation within short distances. The materials are derived from the rocks of the Rocky mountains to the west and, to some extent, of the more resistant materials of the lower rocks which have been reworked into the gravel beds. The Pleistocene beds of the High Plains are known as the Tule or Rock Creek beds and, in a general way, may be considered as belonging to the widespread Lafayette formation. The Tule or Rock Creek beds are thin in most places but locally reach a thickness of 300 feet.

"Caliche" occurs but it is not so widespread as in regions in which the bedrocks are more calcareous. The "Cap Rock" is principally a development of "Caliche."

CORDILLERAN REGION IN TRANS-PECOS TEXAS.

The Cordilleran region in trans-Pecos Texas, is the southern continuation of the eastern ranges of the Rocky mountain system. The area is the western half of trans-Pecos Texas, and contains El Paso, Jeff Davis and Presidio and the greater parts of Brewster and Culberson counties.

The region is one of low, plateau-type mountains separated by low plains. The altitude varies from about 1,500 feet in the valley of the Rio Grande in the southeastern part of the region to about 8,700 feet in El Capitan, the principal peak of the Guadalupe mountains.

Three mountain ranges with two intervening valleys extend parallel to each other across the region in a northwest-southeast direction.

The western range is the Franklin mountains which extends northward from near El Paso and is continuous with the Organ and San Andreas mountains of New Mexico.

The middle range consists of the Diablo plateau which has series of peaks or hills along its western and eastern margins. The western division of the middle range includes the Hueco, Cerro Alto, Finlay, Sierra Blanca, Malone, Quitman, Devil's Ridge, and Eagle mountains and the eastern line is made up of the Carnudas, Sierra Diablo, Baylor, Carriso, Van Horn, Tierra Vieja, Chinati Crenaga, Sierra Bafecillos and Mesa de Anguila.

The eastern or front range enters Texas from New Mexico as the Guadalupe mountains and continues to the southeast as the Delaware, Davis, Mount Ord, Santiago and Sierra del Carmen.

In its broad features, the structure of the region consists of two great anticlinal arches, whose axes correspond in a general way with the eastern and western ranges just described. The Diablo plateau with its subsidiary mountains occupies the synclinal trough between the two great anticlines. In its details the structure is quite complex, showing much minor folding and faulting. The great mountain-making movements took place in late Pliocene or Pleistocene time. An earlier period of folding is shown where erosion has cut through the younger and into the older rocks. This folding took place in late Paleozoic times, at the same time as the folding at the Arbuckle, Wichita and Llano-Burnet mountains.

The details of the stratigraphy have been worked out in only a few localities and it is possible to give here only the major features so far as known.

The Upper Cambrian is represented by sandstone and conglomerate from 300 to 700 feet thick. The Ordovician rocks consist of dolomitic limestone about 1,250 feet thick in the El Paso region and shales, sandstones, limestones and cherts about 2,000 feet thick in the Marathon region. The only Silurian rocks known in Texas are limestones about 1,000 feet thick which are found in the Franklin and Hueco mountains and the upper part of a chert formation in the Marathon region. No rocks, which are certainly of Devonian or Mississippian age, are known, but a novaculite in the Marathon region is probably Devonian and a chert formation in the same region has been regarded as Mississippian.

The Pennsylvanian in the southern part of the trans-Pecos region consists of a great thickness of all the common types of sedimentary rocks, with shales and sandstones predominating. The thickness of these beds in the Marathon region is about 5,000 feet. in the vicinity of Shafter in Presidio county the upper Pennsylvanian is represented by about 4,500 feet of sandstone and shale with minor amounts of limestone. In the northern part of the region, the Pennsylvanian shows a very different aspect from that shown in the southern trans-Pecos or in central Texas and consists almost entirely of limestone (Hueco limestone.) The thickness is about 5,000 feet.

The Permian in the Marathon and Shafter regions is largely calcareous but contains considerable clastic material. In the Marathon region the beds attain a maximum thickness of over 6,000 feet. In the northern trans-Pecos, the Permian has been divided into the Delawaree mountain formation, Capitan limestone, Castile gypsum and Rustler formation. The Castile gypsum is probably equivalent to the Capitan limestone. No Triassic rocks are known in trans-Pecos Texas. Jurassic rocks (Malone formation) are present in the Malone mountains. They consist of blue and gray limestones with smaller amounts of shales, sandstones and conglomerates, having a thickness of from 1,500 to 2,000 feet. The beds represent only the later part of the Jurassic period.

The Comanchean is well represented and has a wide areal distribution. Some beds in the Malone mountains probably belong to the lowest Comanchean, but their thickness and extent are unknown. The Trinity division is represented by sandstones, clays, conglomerates and siliceous limestones. There is much variation in the section in different parts of the region. The entire thickness of the Trinity is over 1,000 feet. In general the Trinity lies unconformably on Pennsylvanian or Permian beds. The Fredericksburg division reaches a maximum thickness of about 1,275 feet and is composed principally of limestone although sandstones predominate locally. The Washita division is present and is represented by the

same type of beds as in north-central Texas, but they have not been sufficiently studied to permit of definite correlations being made.

The Upper Cretaceous is in general similar to that of central Texas. The Eagle Ford shale, Austin chalk, Taylor marl and Navarro formation are all represented. The thickness of the Upper Cretaceous is in excess of 2,500 feet but all the formations are not known to be present in a single locality.

Igneous rocks of many different varieties both intrusive and extrusive are abundant in the trans-Pecos region. A considerable portion of the territory is covered by rhyolitic flows and several of the mountains are composed of intrusive igneous rocks.

The inter-montane valleys are partially filled with Quaternary alluvium or "Bolson" deposits which may reach a thickness of 1,000 feet or more. "Caliche" is of common occurrence throughout most of the region.

TOYAH BASIN.

The Toyah Basin region is a large, "Bolson" filled valley of the trans-Pecos region, but on account of its size is usually considered as a distinct physiographic sub-province.

EDWARDS PLATEAU.

The Edwards plateau comprises a large area in south-central Texas. Its boundaries are the north-central plains and the Llano-Burnet region on the northeast; the Balcones escarpment, which separates the plateau from the Gulf Coastal plain to the southeast; the Rio Grande and the Cordilleran region of trans-Pecos Texas, to the south and southwest; and the Toyah basin and High (Staked) plains to the northwest. Pecos river cuts the Edwards plateau in a deep channel, and the portion of the plateau southwest of the Pecos may be distinguished as a separate sub-province, the trans-Pecos plains. The Edwards plateau comprises all or parts of the following counties: Glasscock, Sterling, Coke, Tom Green, Concho, McCulloch, Menard, Mason, Gillespie, Blanco, Travis, Hays, Comal, Kendall, Kerr, Kimble, Sutton, Schleicher, Irion, Reagan, Upton, Crane, Crockett, Val Verde, Edwards, Real, Bandera, Bexar, Medina, Uvalde and Kinney, and the trans-Pecos plains contain all of Terrell, most of Pecos, and small portions of Brewster and Reeves.

The surface of the area is characterized by broad flat-topped areas separated by narrow canyons. The principal streams have cut deep and rather narrow canyons into the plateau. The rainfall is slight, and the entire area is devoted to grazing. The streams are all intermittent through most of their courses, with permanent waterholes locally. Timber is practically absent, some small mesquite on the lower lands, some small cedars along the "breaks," and a few larger trees near the waterholes, being the only growths.

The surface rocks of the plateau are of Comanchean age. The Comanche Peak and Edwards limestones of the Fredericksburg division are the surficial formation over about 90 per cent of the area. The Glen Rose formation of the Trinity division, outcrops in the deeper valleys, and the formations of Washita division are present in a fringe along the southeastern and southern margins of the area.

The stratigraphic succession of the area is as follows:

COMANCHEAN (LOWER CRETACEOUS) SYSTEM.

Washita division
- Buda limestone
- Del Rio clay
- Georgetown formation

Fredericksburg division
- Edwards limestone
- Comanche peak limestone
- Walnut clays

Trinity division
- Paluxy sands
- Glen Rose formation
- Travis Peak formation (Basement sands.)

The beds are described in the following paragraphs beginning with the lowest.

Travis Peak formation: The Travis Peak formation, which corresponds to the beds known as the Basement sands in the north-central part of Texas, lies unconformably on the steeply dipping Paleozoic rocks around the southeastern and southern margin of the Llano-Burnet uplift. Here the lower part consists of conglomerates, sands and bluish clay shale, and the upper part of calcareous sandstone, marly and mieaceous limestone with bands of conglomerate. The whole formation is from 250 to 300 feet in thickness. The character and thickness of the formation in its southern extent beneath the younger beds of the Edwards plateau is unknown.

Glen Rose formation: This formation outcrops in nearly all the deeper valleys of the Edwards plateau. In the northern part of the region it consists of thin even-bedded, chalky limestones, usually gray to yellow in color, separated by thin beds of sandy and calcareous or marly clay. The average thickness is about 300 to 400 feet, but there is much variation in thickness. The formation thickens from west to east. Borings in the vicinity of Austin show the thickness to be about 600 feet. Southward toward the Rio Grande, the Glen Rose grades into a hard limestone which is with difficulty separated from the overlying beds.

Paluxy sand: This formation is an important member of the Trinity division in part of north-central Texas, but it thins to the

south and disappears in Travis and Burnet counties near the northern margin of the Edwards plateau.

Walnut clays: This formation, the lowermost of the Fredericksburg division, is very distinct in the region northeast of the Llano-Burnet uplift, but in the Edwards plateau it either is absent or has changed in character until it can not be separated from the overlying Comanche Peak limestone.

Comanche Peak limestone: The Comanche Peak formation in the Edwards plateau consists of about 50 feet of argillaceous and marly, white limestone, which generally weathers to a buff color. It is usually softer and more porous and the weathered surface is of a somewhat darker color than that of the overlying Edwards limestone but the two formations grade into each other and their separation must be made on paleontologic grounds. The Comanche Peak outcrops on the slopes of the deeper valleys.

Edwards (*Caprina, Barton Creek*) *limestone*: The Edwards limestone is a hard white limestone containing many flint concretions. In the Edwards plateau, the Edwards limestone covers by far the greater part of the surface and is responsible for the character of the topography and soil. The thickness of the Edwards in this region is about 300 feet. It has been ascribed a thickness of over 600 feet near the Rio Grande but this includes both higher and lower beds which become very similar to the Edwards toward the south.

Georgetown formation: In the Edwards plateau the Georgetown is represented by limestone not easily distinguished from the underlying Edwards, and to the south toward the Rio Grande it has not been differentiated.

Del Rio clay: The Del Rio clay is typically developed in the area under consideration. It consists of greenish, laminatel pyritiferous and gypsiferous clay, with thin slabs of shell breccia, and thin layers of arenaceous limestone. The thickness varies from 30 to 200 feet.

Buda (*Shoal Creek, Vola*) *limestone*: The Buda limestone is a white to yellowish limestone, fairly soft, thin-bedded in the lower part and heavy-bedded above. Its thickness is about 80 feet along the Rio Grande, thinning northward to less than one foot along Brazos river. The Buda outcrops along the Balcones escarpment and covers considerable areas in the southern and southwestern parts of the Edwards Plateau, especially in the trans-Pecos plains.

"Caliche" of recent age is of common occurrence.

Igneous rocks: Along the Balcones escarpment at the south eastern edge of the Edwards plateau, there are notable intrusions of basalt and phonolite. The intrusions are probably early Eocene in age. In the western part of the trans-Pecos plains, there are igneous rocks belonging to the Cordilleran province.

Structure—The structure of the Edwards plateau is very simple. The rocks in general have a very gentle dip to the south and southeast. Over much of the region the dip is so slight that beds must be followed for a considerable distance to determine the dip. Toward the southeast in the vicinity of the Balcones escarpment the dip increases rapidly to 70 or 80 feet to the mile. The Balcones escarpment is a faulted zone and the faulting combined with the igneous intrusions mentioned above produces very complicated structure which is well shown on the United States Geological Survey map of the Uvalde quadrangle. Within the Edwards plateau one anticlinal fold of some magnitude is shown on the map of the Nueces quadrangle. The fold is in southern Edwards county along West Nueces river.

BLACK AND GRAND PRAIRIES.

The Black and Grand prairies region is bounded on the west by the North-central plains (Pennsylvanian area) and on the east by the Gulf Coastal plain. To the north the region extends into Oklahoma. To the south the Edwards plateau may be regarded as the continuation and expansion of the Grand prairie, while the Black prairie is continued as a narrow belt along the Balcones escarpment to Red river and on into Mexico. The region is underlain by rocks of Comanchean and Cretaceous age. The two systems are very similar in general characteristics, both having important beds of sand at the base, and having their upper parts composed of clays, marls and limestones. Most of the limestone and marl formations weather to form a deep, rich, prairie soil which gives the names of the region. The region as a whole may be divided into four areas, beginning at the west.

1. *West cross-timbers,* formed by the outcrop of the Trinity sand at the base of the Comanchean. This is a belt of considerable relief, of very sandy soil, mostly covered with a fairly dense growth of scrub oak.

2. *Grand prairie,* formed by the outcrop of the limestone and clay formations of the Comanchean. The topography is "stair-step" with the resistant beds forming escarpments facing northwest. The soil is generally deep and rich, although some of the limestones have a thin rocky soil. The area is treeless except along the streams.

3. *East cross-timbers,* formed by the outcrop of the Woodbine (Dakota) sand at the base of the Cretaceous. The topography and other characteristics of the area are very similar to those of West cross-timbers.

4. *Black Prairie,* formed by the outcrop of the clays, marls and limestones of the Cretaceous. The territory is similar to the Grand prairie, except that the formations are usually softer and weather

more readily, producing a deeper soil and a more regular topography.

The region as a whole, includes all or part of the following counties: Bowie, Red River, Lamar, Delta, Hopkins, Fannin, Hunt, Grayson, Cooke, Montague, Wise, Jack, Denton, Collin, Rockwall, Kaufman, Dallas, Tarrant, Parker, Hood, Erath, Eastland, Johnson, Ellis, Navarro, Hill, Bosque, Comanche, Brown, Mills, Hamilton, Correll, McLennan, Falls, Bell, Lampasas, Burnet, Williamson, Travis, Hays, Caldwell, Comal, Guadalupe, Bexar, Medina, Uvalde, Kinney, Val Verde and Maverick.

The stratigraphic succession of the beds in the Black and Grand prairies is as follows:

CRETACEOUS SYSTEM.

Navarro formation.
Taylor formation.
Austin chalk.
Eagle Ford formation.
Woodbine formation (present only in north part of region.)

COMANCHEAN SYSTEM.

Washita Division.

South.	North.
Buda limestone	Represented by part of Woodbine formation
Del Rio clay	Pottsboro sub-group
Georgetown formation	Grayson marls.
	Mainstreet limestone
	Denton sub-group
	Ft. Worth limestone
	Buck Creek formation
	Kiamitia clay.

Fredericksburg Division.

South.	North.
Edwards limestone	Goodland limestone
Comanche Peak limestone	Walnut clays
Walnut clays	

Trinity Division.

South.	North.
Paluxy formation	Antlers sand
Glen Rose formation	
Basement sands	

The variations in the section are shown in fig. 60 and 61.

COMANCHEAN SYSTEM.

Trinity division: The Trinity division outcrops in the belt along the west side of the region which is known as the West cross-timbers. In the northern part of the region, from Red river south to Parker and Wise counties the whole division is represented by sands which

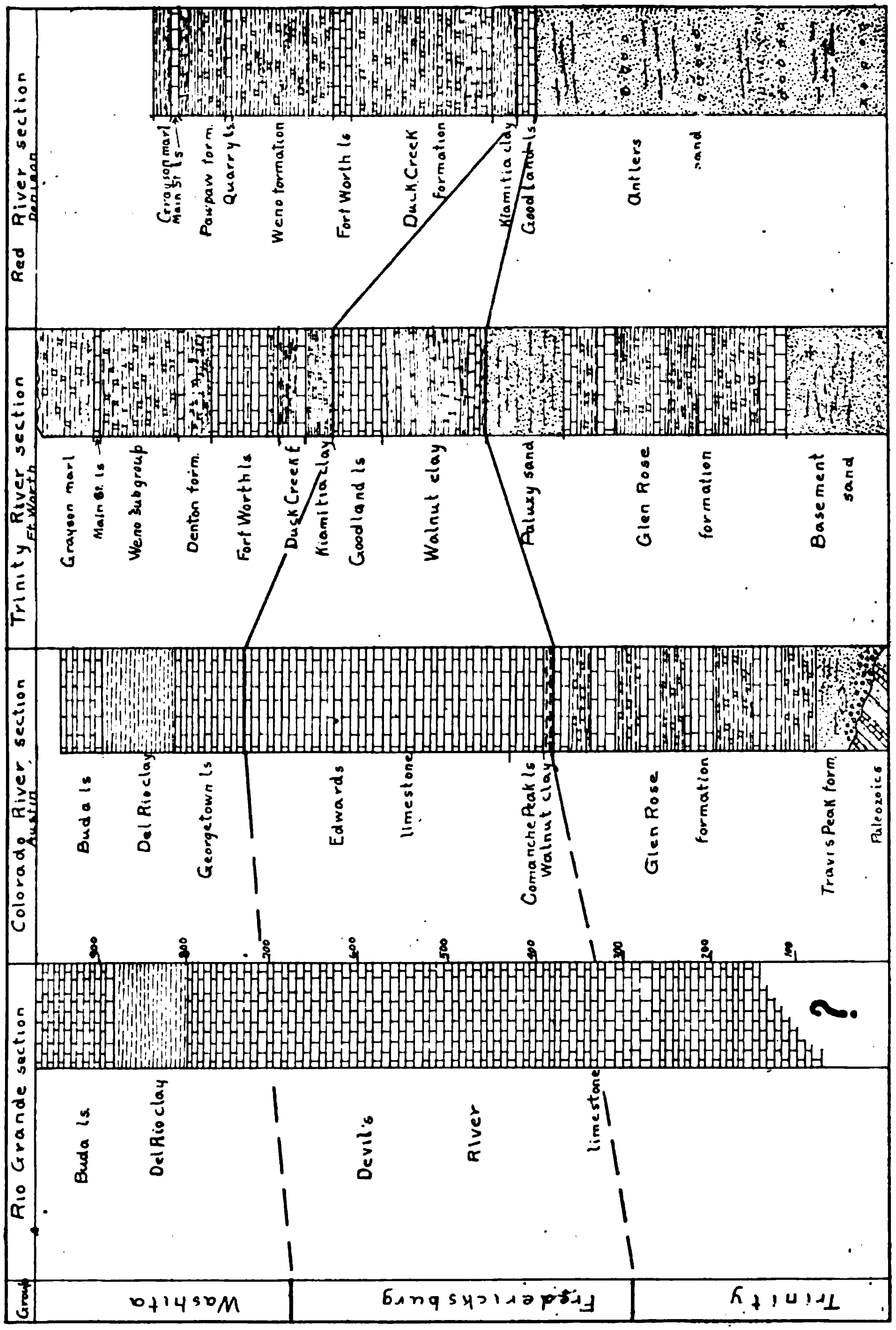

Fig. 60 Columnar sections of the Comanchean system in Texas.

are known as the Antlers sand. South of Parker and Wise counties, a limestone formation is present in the middle of the division. This makes a three-fold division of the Trinity with the Basement sands at the base, the Glen Rose (limestone) formation in the middle and the Paluxy sands at the top. The Paluxy sands have a maximum thickness of about 100 feet. The Glen Rose formation is about 300 feet thick in the southern part of the region, but thins and disappears to the north. The Basement sands are from 50 to 120 feet thick in the south part of the region. The sands, representing the whole Trinity division, in the north part of the region, range from about 300 to 500 feet in thickness.

Fredericksburg division: The *Walnut clays* are composed of marly laminated, yellow clays, within semi-crystalline limestone flags. The beds thicken northwards from about 25 feet in the valley of Bosque river to about 200 feet near Red river.

The *Comanche Peak limestone* is about 50 feet thick in the southern part of the area, and the *Edwards limestone* is about 300 feet thick. They both thin to the northward and cannot be distinguished from each other. In the extreme northern part of the area both are represented by the Goodland limestone which is from 15 to 50 feet thick. The Goodland forms a very pronounced northwestward facing escarpment above the soft Antlers sand.

Washita division: This division varies greatly in character from north to south and many names have been applied to the subdivisions. The *Georgetown formation*, consisting of gray marly limestone, with marls and shales, is about 80 feet thick in the southern part of the region. North of Little river the lower part of these beds changes to dark blue, bituminous, laminated clays with thin beds of impure bituminous limestone. These are known as the *Kiamitia clays* and reach a thickness of about 150 feet. The upper, calcareous part of the formation is known as the *Fort Worth limestone*. Northward from Brazos river still other beds appear. Between the Kiamitia clays and the Fort Worth limestone, a series of white, chalky limestones and blue marls appear. This series is known as the *Duck Creek formation*. It is 40 feet thick at Fort Worth and 194 feet at Denison. The Kiamitia clays and Duck creek formations have been grouped together as the Preston beds.

The Fort Worth limestone continues through to Red river with a fairly uniform thickness of about 100 feet.

North of the Trinity river, several beds come in above the Fort Worth limestone. These are with their greatest thickness as follows:

Weno sub-group	
Pawpaw beds	40 feet
Quarry limestone	5 feet
Weno formation	40 feet
Denton sub-group	35 feet

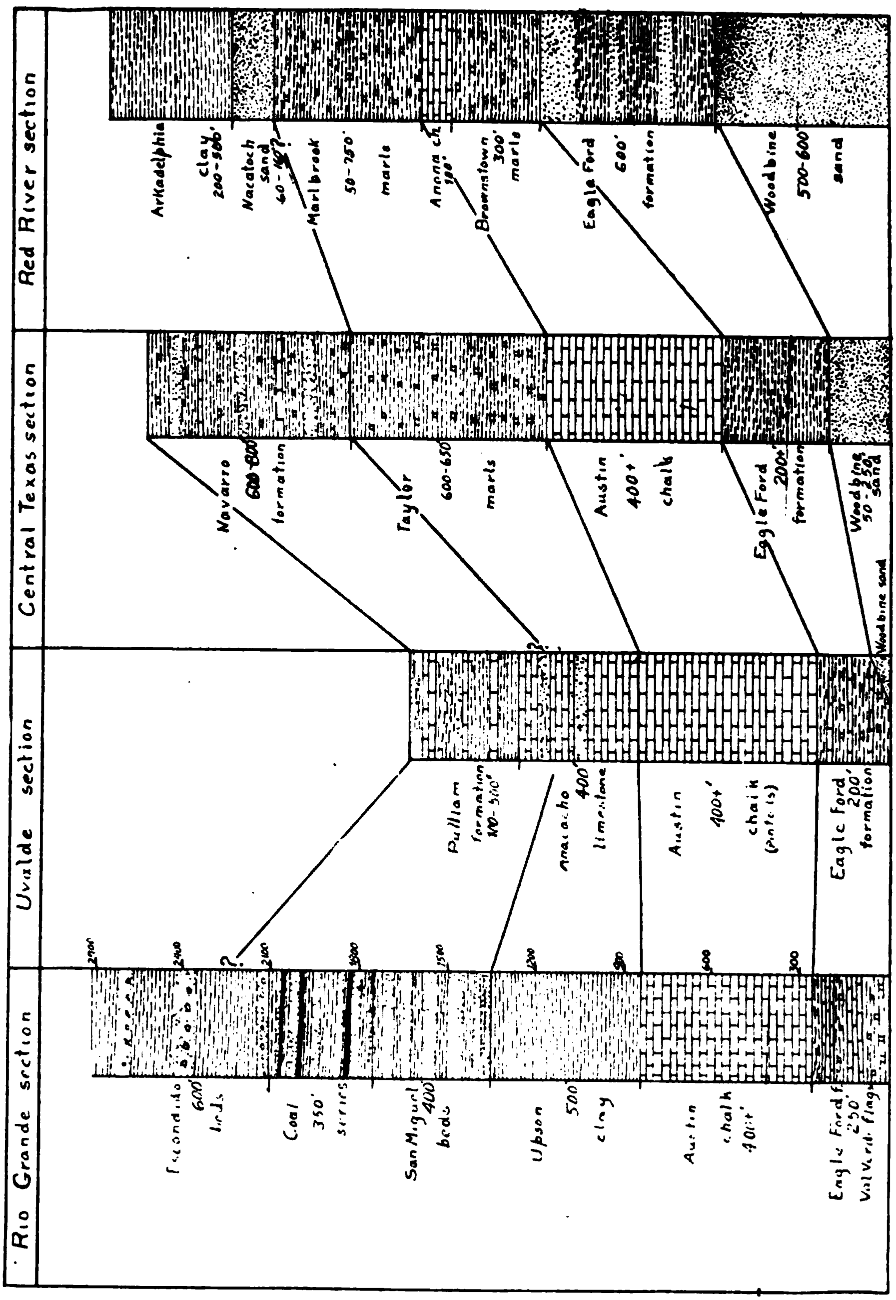

Fig. 61—Columnar section of the Cretaceous system in Texas.

All these beds consist principally of marl and clay with some sand in the Weno formation. All these beds represent the extreme upper part of the Georgetown formation.

The *Del Rio clay* as recognized in the Edwards plateau continues northward to Brazos river. Farther north it grades imperceptibly into white marly limestones and yellow marls. These beds are known as the *Pottsboro sub-group* and are divided into the *Mainstreet limestone* below and the *Grayson marls* above. The Mainstreet (named from exposures on Main street, Denison) limetone is from 15 to 25 feet thick and the Grayson marls about 50 feet thick.

The *Buda limestone* of the Edwards plateau disappears near Brazos river. To the northward it is probably represented by the lower part of the Woodbine formation, which, however, is generally considered to be of Cretaceous age.

CRETACEOUS SYSTEM.

Woodbine formation: As indicated in the preceding paragraph, this formation includes the equivalent of the Buda limestone. The Woodbine consists largely of ferruginous, argillaceous sands, brown to red in color, accompanied by bituminous, laminated beds. The formation is about 500 feet thick at Red river but thins rapidly to the south, and disappears near Brazos river.

Eagle Ford formation: The Eagle Ford shale in the north part of Texas, is composed of blue and black laminated clays with large septaria, sands, shales, and thin layers of brown limestone. The upper sandy part has been called the Blossom sand. Southward the formation becomes in part more calcareous and in part more sandy, and near the Rio Grande it consists of thin bedded limestone alternating with marly clay to which the name Val Verde flags has been applied. The thickness varies, in the northern part of the state it is about 600 feet, decreasing southward to about 50 feet near Austin, and then increasing to 200 to 250 feet near the Rio Grande. Westward along the Rio Grande the formation thickens to 600 feet.

Austin chalk: The Austin chalk consists of fairly thick-bedded impure chalk, containing nodules of pyrite and interstratified with marly beds. The upper part generally contains more marl and less chalk than the lower part. Near Red river the Austin chalk is represented by two formations, the Brownstown marls below and the Anona chalk above. Near the Rio Grande the formation loses its chalky character and hard, white limestone predominates. This phase of the formation has been called the Pinto formation. The thickness of the Austin chalk varies from about 400 feet to about 750 feet.

Taylor formation: This formation consists of laminated calcareous, bluish black marls, which weather into a whitish yellow

clay. The boundary between the Taylor marls and the overlying Navarro formation cannot be definitely located since the formations are very similar and grade into each other. In the Red river region, the Taylor is probably represented by the Marlbrook (Kickapoo) marls. On the Rio Grande, the Upson clays, a dark gray or greenish gray clay, weathering yellow and containing crystals and seams of gypsum, probably represents the Taylor formation.

In the Uvalde region and in the Anacacho mountains in Kinney county the Upson clays are replaced by the Anacacho formation, a series of yellow limestones and calcareous sandstones. The upper parts of ths formation probably represent part of the Navarro formation. The Taylor marls are about 600 feet thick; the Upson clays about 500 feet thick, and the Anacacho formation about 400 feet thick.

Navarro formation: The Taylor marls grade upward in the glauconitic marls of the Navarro formation which also contains some limestone, black clays and sandstone. The character of the Navarro changes so rapidly that several names have been applied to the formation and its sub-divisions. Besides the name Navarro, the formation, as a whole, has been called the Upper Arenaceous series, the Glauconitic division, Webberville beds and the Bexar formation. In the vicinity of Red river the Navarro is divided into the Nacatoch sand member, consisting principally of glauconitic sand, 60 to 160 feet thick, and the Arkadelphia clay, consisting of dark laminated clay, 200 to 500 feet thick. In the vicinity of Corsicana, two sub-divisions are recognized, the Corsicana beds and the Kemp beds. The name Webberville formation was applied to the whole series of beds in the vicinity of Austin.

In the Uvalde region the Navarro is represented by the top part of the Anacacho limestone and by the Pulliam formation which consists of brown ferruginous sandstone with clays and marls and some hard limestones. Near the Rio Grande, the equivalents of the Navarro formation are known as the Eagle Pass formation which consists of:

1. San Miguel beds, gray and brown, quartzitic and calcareous sandstone interbedded with clays and shales.
2. Coal series, clays, dark shales, and white and yellow sandstones, with seams of coal and fire clay.
3. Escondido beds, white yellow to brown sands, sandstones, and conglomerates, with greenish blue clays and some gray limestone.

The thickness of the Navarro cannot be determined definitely on account of the indistinct separation between this formation and the Taylor, but it is probably 600 to 800 feet.

The variations in the Cretaceous sections are shown in fig. 60.

GULF-COASTAL PLAIN.

From a physiographical standpoint, the Gulf Coastal plain lies between the Balcones fault zone and the Gulf of Mexico, but for the purposes of this book it seems best to consider the region as beginning at the contact between the Cretaceous and Eocene rocks. The region is thus co-extensive with the area of the Tertiary and Quaternary rocks of the Gulf Coast.

The region includes all the counties lying south and east of a line passing through Bowie, Titus, Hopkins, Hunt, Kaufman, Henderson, Navarro, Limestone, Falls, Milam, Williamson, Bastrop, Caldwell, Guadalupe, Bexar, Medina, Uvalde, Zavalla and Maverick counties.

The Gulf Coastal plain is a region of low relief. For a distance of 50 to 100 miles from the coast the slope is very gentle, about one foot per mile. Farther back the slope is steeper and the relief is greater. The topographic features are broad valleys and broad flat ridges which slope to the southeast.

At the beginning of Tertiary times there were two great embayments, one along the present course of the Rio Grande and one along the Mississippi. The divide between Colorado and Brazos rivers marks the division between these embayments, and the early Tertiary sediments show great variation to the north and to the south of this divide. The embayments are not well marked after the close of the Oligocene.

The Tertiary and Pleistocene rocks are mostly unindurated sands and clays, with some gravels, beds of lignite and a few limestones.

The rocks dip gently to the south, southeast or east toward the Gulf of Mexico. The rate of dip is greater than the slope of the surface so that successively younger beds are encountered as the Gulf is approached.

There are probably many variations in the structure but owing to the unindurated nature of the rocks exposures are very scarce and the individual beds are hard to follow, so that the presence of minor structures is very difficult or impossible to determine in most of the region.

The stratigraphic succession is as follows:

Quaternary

Recent.
Pleistocene.

East Gulf Coast.	*West Gulf Coast.*
Port Hudson-Columbia	Port Hudson-Columbia
(Beaumont or coast clays)	Equus beds
Lafayette (Lizzie)	Uvalde, Reynosa

Tertiary	
Pliocene	
Fleming (in part)	Lagarto
	Lajara
Miocene	
Fleming (in part)	Oakville.
Oligocene	
Corrigan or Catahoula	(Absent)
Eocene	
Jackson	(Absent)
Claiborne	Claiborne
(Absent)	Frio
(Absent)	Fayette
Yegua or Cockfield	Yegua
Cook Mountain	Cook Mountain
Mount Selman	Mount Selman
Queen City-Carriso	Carriso
Wilcox	Wilcox
Midway.	Midway (Myrick)

EOCENE SYSTEM.

Midway Group.

The Midway consists in Eastern Texas predominantly of clays and in southwestern Texas is more sandy and has some marine limestone near the base. The thickness varies from 200 to 400 feet. The Midway is also known as the Basal Eocene and Will's Point.

Wilcox Group.

The Wilcox is marine in the vicinity of the Sabine river, where both the upper and lower Wilcox of the Alabama section is represented. The non-marine Wilcox in northeastern Texas is composed of sands, sandstones and clays, with some beds of lignite, the whole having a thickness of 800 to 1,200 feet. The Wilcox in places overlaps the Midway and rests upon the Cretaceous. The Wilcox in the western part of the region consists principally of siliceous sands, with small amounts of glauconitic sands, vari-colored clays and beds of lignite. In the extreme western part of the area the Wilcox forms the middle part of what has been mapped as the Myrick formation, and is about 800 feet thick.

Claiborne Group.

The lowest formation of this group is called the Queen City in the eastern part of the region and the Carrizo in the west. It is the upper part of the Myrick formation of the Uvalde region. The Queen City-Carrizo formation is dominantly sandy and has a thickness of from 50 to 200 feet.

The Mount Selman in eastern Texas is made up of dark green and brown sands, with thin beds of iron ore and lignite and beds

and concretions of limonite. The workable iron ore is limonite concentrated near the surface. In the western part of the area, the Mount Selman consists of ferruginous sands and sandstones, or altered glauconite, with rounded calcareous sandstone concretions, carrying marine fossils in places, and beds of clay and shale. The thickness of the formation in the eastern region is about 350 feet and in the western from 225 to 475 feet.

The Cook Mountain formation is very similar to the Mount Selman in both parts of the region. The thickness in the eastern part of the region is about 400 feet and in the western part about 540 feet.

The Yegua formation is only partly of marine origin. It is dominantly clay in the lower part and sand in the upper. Important beds of lignite are present in the middle part of the formation. Along the Rio Grande the Yegua contains some limestone and gypsum. The thickness varies irregularly from 375 feet in the eastern part of the region to 1,400 feet at the Rio Grande.

The Fayette formation consists principally of sands and sandstones with some beds of lignitic clays and lignite. The sands are locally indurated to a condition approaching that of quartzite, silicified wood is common. The thickness of the formation is from 400 to 600 feet. The Fayette is not known to occur east of Brazos river.

The Frio formation is composed largely of yellow and dark clays, which weather white, with some gypsum and volcanic ash. The formation is about 660 feet thick near the Rio Grande but thins to the northeast and disappears about Colorado river.

Jackson Group.

The Jackson is present only in the portion of the region east of Brazos river. The formation consists of clays and sands of different characteristics. The greater part of the formation is marine. At least two beds of volcanic ash are present in the upper part of the formation. The formation has a thickness of 400 to 500 feet.

OLIGOCENE SYSTEM.

The Corrigan (Catahoula, Grand Gulf) has been provisionally correlated with the Grand Gulf Oligocene. It consists of coarse "rice" sand and sandstone at the base, overlain by finer sands and by yellowish green clay and claystones with plant remains. The formation is non-marine and occurs only in the eastern part of the Gulf Coast region. The thickness ranges from 250 feet to 600 feet.

MIOCENE AND PLIOCENE SYSTEMS.

In the eastern part of the Gulf Coast region the Miocene and Pliocene systems are represented by the Fleming formation. It is

composed of clays and sands with quantities of calcareous concretions. The clay is generally light colored, but weathers to a black, sticky soil. In the western part of the region, the Fleming is represented by the Oakville, Lapara and Lagarto formations which consist of generally unconsolidated sand and clays.

PLEISTOCENE SYSTEM.

The Pleistocene system is represented principally by the Lafayette formation or its equivalents which cover considerable areas, not only in the Gulf Coastal plain but also in other areas in Texas. The Lafayette consists principally of sand with varying proportions of conglomerate. The nature of the pebbles in the conglomerate differs greatly in different localities, being derived from the older rocks in the vicinity. The Lafayette, or its equivalent, overlaps most of the older formations; and forms a blanket over the uplands, and terraces along the streams. The bedding of the Lafayette is very irregular and, since it effectually obscures the older rocks, the structure cannot be determined in the areas in which it occurs in any thickness. In the vicinity of the Rio Grande the Pleistocene gravels and sands are known as the Reynosa formation and in the Uvalde region as the Uvalde formation and on the eastern Gulf Coast as the Lizzie. They correspond in a general way to the Seymour and Tule or Rock Creek beds of the Great Plains areas. In thickness the Lafayette varies from a very thin mantle to 500 or possibly 800 feet along the Gulf Coast and to over 1,000 feet in the inter-montane valleys in trans-Pecos Texas.

Port Hudson and Columbia formations—These formations are closely related. The Port Hudson occurs along the Gulf Coast lowlands and the Columbia includes the deposits of the "second bottom" terraces of the rivers and grades into the Port Hudson near the Gulf. The Columbia extends far up the major streams across the Black and Grand prairies and into the north-central plains.

The Port Hudson consists of blue, yellow, brown and, in places, reddish limy clays, with numerous small lime concretions. The composition of the Columbia is quite similar to that of the Port Hudson but it contains a somewhat greater proportion of sandy material.

The material of the coastal marshes and of the flood plains of the streams is of recent age.

V.

GEOLOGIC CONDITIONS IN KANSAS, OKLAHOMA AND AND TEXAS WITH SPECIAL REFERENCE TO PROSPECTS FOR OIL AND GAS.

Brief mention of the occurrence of oil and gas of the different geologic provinces of Kansas, Oklahoma and Texas has been made in the preceding section. However, it seems best to consider at somewhat greater length the relation of the geologic conditions to the occurrence and accumulation of oil and gas in each of the regions or areas described.

KANSAS.

Mississippian area—Mississippian rocks occupy only a few square miles in the extreme southeastern corner of the State. This area is part of the Ozark mountain region, which occupies a much larger area in Oklahoma. The region is practically without chance for commercial production of either oil or gas for reasons which are discussed under the Ozark mountain region of Oklahoma.

Pennsylvanian area—The rocks of the Pennsylvanian system were laid down under conditions very favorable for the burial and preservation of considerable quantities of organic matter. They are deposits which were laid down in comparatively shallow water, and were built up rapidly. They consist largely of bituminous clays and shales, which contain ample supplies of bituminous materials, and also sufficient sands to act as reservoirs for the accumulated oil or gas. The sands are well sealed by the shales with which they are associated.

The structural features are not pronounced. The general dip of the Pennsylvanian beds is about 30 feet per mile to the north of west, away from the Ozark mountains. There are many small wrinkles and terraces and a few well-defined anticlines.

The conditions are thus very favorable for the production and accumulation of oil and gas, and we find that all the oil and gas so far produced from Kansas come from these rocks.

The areas of production are described in the succeeding section and need not be discussed in this connection.

Some features, however, should be noticed. An examination of the map, (fig. 47) will show three principal areas of production (1) a belt through Montgomery, Chautauqua, Neosho, Wilson

and Allen counties; (2) an area in Franklin and Miami counties; and (3) a belt through Butler and Cowley counties. These areas are separated from each other by almost barren belts in which the geologic conditions appear, at first glance, to be just as favorable for production as those in the producing areas.

However, the production in the eastern district (Chautauqua, Montgomery, Wilson, Neosho, and Allen counties) comes mainly from a group of sands near the base of the Cherokee formation, the principal one of which is known as the Bartlesville sand. This body of sands thins out and disappears to the west and northwest* so that production must be expected from the higher formations. The clays in these beds as a rule are not so bituminous as those of the Cherokee and the sands are thinner and finer-grained.

The production in Miami and Franklin counties is probably from a higher horizon than that to the south so it does not seem probable that the gap between them will be closed up by important production.

Another noticeable feature is the absence of production from the northern part of the area. The beds in this region seem to have been deposited farther off shore than those to the south. The section is thinner, the clays not so bituminous and sands are almost absent to the north. While there may be some small deposits found in this part of the Pennsylvanian area, the chances for important pools are small.

Most of the northern part of the area is covered with a thin mantle of glacial drift which covers the bed rocks and makes the determination of the structure difficult or impossible so that the more favorable localities for drilling cannot be determined.

Permian area—So far no production has been had from the Permian rocks in Kansas. The surface rocks in the Butler and Cowley county fields are Permian but the production comes from well down in the underlying Pennsylvanian.

In general the Permian rocks are not favorable for oil or gas. The lower part of the system consists principally of limestone; the middle part of gray to blue clay shale; and the upper part of red clays with gypsum and salt and some sands. There does not seem to be the requisite amount of organic matter present in any part of the system to produce much oil or gas, and in the lower and middle parts of the system, which contain more organic matter than the Redbeds, sands are practically absent.

However, the Pennsylvanian beds are in reach of the drill throughout the Permian area and may give production where the conditions are favorable.

*Moore, R. C. Bull. Kans., Geol. Survey, No. 3.

The presence of the granite ridge makes a narrow strip non-prospective territory, since the possibly productive sands are cut out by the granite. The Eldorado and Augusta fields are at the south end of this ridge, and the recent development near Elbing and Peabody is working northward along the western margin. The area actually condemned by the granite ridge is thus made rather small but the distance northward to which production may be carried along the sides of the ridge and the importance of the production is still to be proven.

In general, the probabilities of finding commercial deposits of oil or gas in the Permian area decrease from east to west across the area. This is because the depth to the possibly productive rocks in the Pennsylvanian increases in that direction and also because the beds in the upper part of the Permian are soft and give few outcrops so that, over much of the area, it is impossible to determine the surface structure.

Comanchean area—The area of Comanchean rocks in Kansas is very small. The rocks are not favorable for the presence of oil or gas in quantity and the depth to the Pennsylvanian is so great as to make the possibilities of obtaining production in the area small.

Cretaceous area—The Cretaceous rocks in Kansas belong to the series which underlies the Great plains and a large part of the Rocky mountain region. The rocks consist of shales, sandstone and limestone. The materials were derived from the west and the section in Kansas is considerably thinner than in Colorado and Wyoming.

The Cretaceous system contains the beds which are productive in the light-oil fields of Wyoming, but, so far, the extension into Kansas of the productive sands and of the conditions favorable for accumulation has not been proven. The fields of Wyoming are on pronounced anticlinal structures while in Kansas, so far as known, the rocks dip very gently in a general easterly direction.

The Cretaceous rocks in Kansas are, in large measure, very soft and do not furnish good outcrops so that it is very difficult or impossible to determine the structural conditions over much of the area.

In view of these conditions, the chance for finding oil or gas in quantity in the Cretaceous rocks must be regarded as small, but not as altogether lacking.

Along the eastern margin of the area, the uppermost Pennsylvanian rocks are in reach of the drill. However, since there is a marked unconformity between the Cretaceous and the Pennsylvanian, which prevents the structure of the latter from being determined from the surface, and since the upper part of the Pennsylvanian is not productive farther east, any attempt to secure production from the Pennsylvanian through the Cretaceous is very hazardous.

Tertiary area—The Tertiary sediments in western Kansas are all non-marine and contain no beds giving any possibility of oil or gas. They effectually obscure the structural conditions of the underlying rocks. Any development of oil or gas in the Tertiary region must get production in the underlying Cretaceous rocks and as a result of strictly wild-cat drilling. There is, therefore, very little probability of any development in this area.

Pleistocene area—Considerable areas in northern Kansas are covered with glacial drift or with loess. These deposits merely cover the bed rocks and prevent any determination of structure. The chances for production depend upon the underlying bed-rocks with the added hazard of the necessity for locating tests without reference to the structural conditions.

OKLAHOMA.

Ozark mountain region—From the standpoint of the nature of the rocks and the structure there seems to be no reason why this region should not be productive of oil and gas. The Burgen sandstones is a loosely cemented, porous sand, which would form a good reservoir for oil and gas, and the shales of the Tyner and the Chattanooga shale should form a sufficiently thick impervious layer to make a good cap rock. The rocks are folded so that places where the structural conditions are favorable for accumulation can easily be located. However, up to the present no deposits of either oil or gas of commercial importance are known to have been found in the Boone chert, except near the top of the formation considerably to the west of its outcrop, or from the rocks below it. The fact is recognized by the drillers who almost invariably stop when they are sure that the "Mississippi lime" (that is the Pitkin, Fayetteville and Boone, has been reached. So little detailed geologic work has been done in the region that it is impossible to say whether or not any of these wells have been located where the structural conditions were favorable for the accumulation of oil and gas, but it is highly improbable that all of them should have been located in synclines. The evidence, then, points to the fact that although the nature of the rocks and the structural conditions are favorable for the accumulation of oil and gas if they were present, the Burgen sandstone and the underlying rocks must be barren of the organic matter to produce the oil and gas. So far as known there are no fossils in the Burgen sandstone and fossils are rare in the rocks in Arkansas of the same position and lower. In the absence of oil and gas, these rocks back from the outcrop are filled with salt water in the anticlines as well as in the synclines. The water falls on the outcrops of the older rocks to the east in Arkansas and work down the dip, being kept from escaping to the surface by the Tyner and Chattanooga shales. In the territory along Grand river the water is under sufficient head to rise to

the surface wherever the shales are penetrated. The flowing wells at Vinita, Claremore, Adair and other places in this region are of this type, and it appears that there is practically no hope of obtaining oil or gas in this part of the area. Very few wells have been drilled along the south side of the region, and it may be that small pools may be encountered in this part of the area, although the chance for any development must be regarded as extremely small. Some of the production in the Muskogee district may come from below the Boone chert, possibly from sands within the Chattanooga shale, and this makes some territory in the southwestern portion of the Ozarks worthy of testing, but the areas are small.

Pennsylvanian region—The geologic conditions in this area are extremely favorable for the formation and accumulation of oil and gas. The shales are black and bituminous. The limestones and sometimes the shales and sandstones are fossiliferous. There is thus an abundant supply of organic matter for the formation of oil and gas. The coarse-grained, porous sandstones form excellent reservoirs and the shales by which they are surrounded are impervious and prevent the escape of the oil to the surface. The structure is usually gentle, but is of the type best adapted to the accumulation of large bodies of oil and gas.

The occurrence of important producing areas in this region is to be expected, and it is here that the main fields are found. In the portion of the area north of the Arkansas are the Bartlesville, Delaware-Childers, Coody's Bluff-Alluwe, Osage and other fields; and in the portion south of the Arkansas are the Glenn pool, the Cushing field, the development around Okmulgee, Muskogee and Henryetta, and the gas fields at Poteau and Coalgate. Each of these fields or pools is considered in some detail in a subsequent section.

Ouachita mountain region—In the present state of our knowledge it must be regarded as doubtful whether the Ouachita mountain region contains any oil and gas deposits. No deep drilling has been done in the area in Oklahoma, and the writer knows of none in Arkansas. The rocks, as a rule, are practically barren of fossils, and would consequently not be supposed to produce large quantities of oil or gas. However, the older rocks, *i. e.*, those older than the Stanley shale, are somewhat metamorphosed by the forces which produced the uplift, and it may be that the traces of animal life have been obliterated by the changes which the rocks have undergone. At any rate, the fact that some of the rocks at some time contained considerable deposits of oil is proven by the presence of considerable quantities of asphalt along faults in the McGee and Impson valleys, and in other localities.

The structure of the region is very sharp and faults are very common. Only a few of the faults are known to have asphalt deposits, so that several conditions seem possible. First, the oil de-

posits may have been small and widely separated so that the present asphalt deposits represent all of the ancient oil beds. Second, the oil in escaping to the surface along the fault plains shortly after they were formed may have left the deposits of asphalt very near the surface of that time, and the deposits may have been largely removed by erosion since. Third, some of the oil deposits may not have been affected by the faulting and are still below the surface in some of the more gentle folds. Fourth, some of the faults may have intersected the oil-bearing strata, but may have sealed the deposits instead of allowing the oil to escape to the surface. As stated in the section on accumulation, some of the principal pools in the California fields have this sort of structure. (See fig. 6.)

When everything is considered, it seems as if this area must be considered as unfavorable territory for oil and gas, but there always remains the possibility that some of the more gentle folds or the territory along some of the fault lines may prove productive. The small amount of geologic work which has been done in the region and the fact that nothing has been published on the portion which has been worked make it impossible to point out any localities that are more favorable for prospecting than the others.

Arbuckle mountain region—The general conditions in the Arbuckle mountains are very similar to those in the Ouachita mountains, although the sections themselves are very different. The rocks are much folded and faulted. The presence of large asphalt deposits show that at one time there were extensive deposits of oil, of which the lighter constituents have escaped. These oil deposits were contained in the Simpson formation and possibly in part in the Viola limestone. The question then arises as to whether or not all of the oil has escaped. The presence of some seeps of very heavy oil or viscous asphalt is an indication that the process of asphalt formation is not yet completed, and there may be some bodies of oil totally sealed in from the surface.

The structure in the area of the mountains themselves is such that the presence of such bodies of any great size is extremely improbable. The folds are sharp and are frequently broken by faults which very often bring the Simpson formation, which is the petroliferous horizon, to the surface so that if oil ever was present it has probably escaped. The area has been worked over pretty thoroughly, and no localities are known which seem at all favorable for prospecting.

The conditions in a belt around the mountains may be somewhat more favorable since the older folded rocks were covered by the Pennsylvanian and Permian rocks on the east, north and west in a comparatively short time after the folding of the mountains and after a longer interval by the Cretaceous rocks on the south, and the folds were probably not so deeply eroded as those in the exposed

parts of the mountains are at present. There is also the possibility that the folding and faulting may be less pronounced farther away from the core of the mountains. In either of these conditions the oil may remain in the older rocks, or if it works up out of them there is a strong probability of its being trapped in sandstones or other porous rock before it reaches the surface. These conditions are believed to account for the accumulations in the Wheeler and Madill fields near the Arbuckle mountains. The conditions are discussed more fully in connection with the discussion of the relation of the geology to the prospects for oil and gas in the Red river limestone area and part of the Redbeds area.

Wichita mountain region—It has been noted in the description of the Wichita mountains that they have the same sort of structure and the same geological conditions in general as the Arbuckle mountains except that they were more deeply buried in the Redbeds than the Arbuckles. It follows that the discussion of the prospects for oil and gas in the Arbuckle mountains applies also to the Wichitas. If we restrict the area to the peaks of granite rocks and small areas of limestone to the north of the mountains, the chances may be said to be zero. The conditions around the mountains are the same as those around the Arbuckles, and are considered in connection with the discussion of the Redbeds and with the description of the development at Lawton and Gotebo.

Red river limestone region—The general conditions in the Red river limestone area are shown in the accompanying diagram. The Cretaceous sandstones, shales and limestones lie nearly level above the older rocks of the Arbuckle and Ouachita mountains, which were folded and faulted and worn down before the Cretaceous rocks were deposited over them. The Cretaceous rocks themselves are very fossiliferous, and the character of the rocks of the upper part of the section is such that oil and gas should be formed in them. However, these have been unproductive of oil up to the present. Some good structures have been mapped and drilled but only moderate flows of gas have been encountered.

The Trinity sand, the lowest formation of the Cretaceous, contains practically no plant or animal remains, but on the other hand it does contain several deposits of asphalt which are supposed to be the residue of deposits of petroleum, the lighter ones of which have escaped. In addition to the asphalts, one pool of oil of commercial importance, that at Madill, has been found in this sand in Oklahoma. The origin of this oil and of the asphalt deposits is somewhat uncertain, but it is usually believed to have been formed not in the Trinity itself, but in the underlying older rocks. The Trinity is deposited over the upturned edges of the Pennsylvanian and older rocks, which were folded at the time of the formation of the Arbuckle mountains. The Pennsylvanian rocks and the Simpson

sandstone of the older formations are known to be oil-bearing, as is shown by the asphalt deposits of the Arbuckle mountains and of the Ardmore region. If the oil in these older tilted rocks had not escaped before the Trinity was deposited it would gradually work its way up out of these rocks into the Trinity. If the Trinity was very thin at that locality the oil would probably move on to the surface where the lighter constituents would escape and the heavier ones would be left in the form of asphalt. In this connection it may be said that the Trinity at the Madill pool is about 400 feet thick, while farther north, where most of the asphalt deposits occur, the sand is probably considerably thinner. The basal portion of the Trinity is usually coarser than the higher parts, and thus would afford a place for the accumulation of the oil and gas. If one of these coarser places should be overlaid by very fine or clayey sand the conditions would be very similar to those of sandstone lenses occurring in shale or to local thickening of sandstones which have been mentioned in the discussion of the conditions of accumulation. (See fig. 9.)

The presence of the pool at Madill is not indicated by any surface characteristics, and it is easily seen that accumulations of this kind would not be related to structure of the rocks at the surface or to any surface feature. There may be many such pools in the region, but the drill is the only method of prospecting for them. It seems reasonable to suppose that the chances for such accumulations would be greater back from the outcrop of the Trinity, provided that the rocks underlying the Trinity were equally petroliferous and that they were inclined in the same way that they are near the outcrop.

Redbeds region—The red color of the Redbeds is, in itself, almost conclusive proof that they do not contain any considerable quantity of oil or gas. It was noticed in the sections on origin and accumulation that oil and gas are almost certainly derived from organic matter and that they probably were formed in the rocks in which they now exist or at least have not moved through the rocks for great distances. The red color of the Redbeds is due to the presence of iron in the oxidized form, probably in a form identical with ordinary iron rust. In the presence of organic matter, this red compound is changed chemically to dark-colored, usually black or green compounds. The prevailing red color of these rocks, then, is proof that there was not sufficient organic matter buried with them to effect this change. The quantity required to change the red iron compounds to dark colored compounds is very much less than would be required to give commercial deposits of oil or gas, so that it seems quite certain that there are no deposits of these substances which were formed in the red rocks themselves.

The Redbeds consist so largely of fine-grained clay-shale that it seems impossible for the oil and gas to have migrated for great distances through them, and any deposits which were formed in other rocks and which have moved into the Redbeds must be found very near the rocks from which they came. This reduces the portion of the Redbeds area which can be considered as at all promising for oil and gas to a strip along the eastern margin, where they are sufficiently thin for the underlying non-red rocks to be reached by the drill, and a similar area around the Arbuckle and Wichita mountains and between these mountains and Red river. The probabilities are greater in this region than along the eastern margin because in the southern area the older rocks below the Redbeds are steeply tilted and any oil or gas which was in these rocks has had an opportunity to work up and out into the basal layers of the Redbeds. The conditions in the Wichita mountains are similar, except that the Redbeds come up higher on the older rocks, so that the exposures of the latter are much less than in the Arbuckles. The thickness of the Redbeds increases very rapidly to the north from both groups of mountains, but between the mountains and south to Red river and beyond, the depth to the older rocks is nowhere over a few hundred feet. In this region there is also the possibility of determining the structure, while in the main portion of the area to the north of the mountains there seems to be no evidence of structure, so far as has yet been determined. The production from the Permian area is either from the base of the Permian or from the underlying Pennsylvanian. The Kay county, Billings, Garber, Healdton, Loco, Fox, Stephens county, Lawton, Walters and Gotebo fields are all located in the area of Permian rocks.

TEXAS.

Llano-Burnet region—The rocks of the Llano-Burnet uplift range in age from pre-Cambrian to Ordovician with a fringe of the Bend series of Pennsylvanian age around the northern and eastern side of the area. The pre-Cambrain rocks are granites and very strongly metamorphosed schists and gneisses which give no possibility whatever for oil or gas. The Cambrian rocks are sandstones and hard, dense limestones with thin shales which are not bituminous. The Cambro-Ordovician consists of dense, white to gray, non-bituminous limestone which gives no indication of containing oil or gas. The Bend series contains notable deposits of oil and gas at some distance north of the mountains, but where it is present within the region of the uplift, it is so near the surface that there is little or no possibility of its containing oil or gas. There is, therefore, practically no possibility of oil or gas being found in the Llano-Burnet region.

North-central plains—The remarks made concerning the Pennsylvanian areas of Kansas and Oklahoma apply to the Pennsylvanian area which makes up the eastern part of the north-central plains of Texas. The rocks are shales and sandstones with some limestones, which dip to the west and northwest at about 60 to 70 feet to the mile.

Up to the present the important oil and gas production has come from the Bend series at the base of the Pennsylvanian; the Strawn formation is productive in the Strawn and Moran fields and has given showings in several localities. The Canyon formation has not given any production nor has the Cisco, unless the lower sands in the Electra-Petrolia region belong to this formation.

In the greater part of the area, then, we must look to the Bend series for production. This series is separated from the overlying beds by a pronounced unconformity and apparently suffered some deformation before the upper beds were deposited, so that the beds of the Bend are not parallel to the surface rocks. The exact relationships of the production in the Bend to the structural conditions are not yet definitely decided, but the concensus of opinion may be summarized as follows:

(1) The production in the Bend is along anticlinal folds in that formation.

(2) The structural conditions in the Bend are not necessarily shown at the surface, although they are usually reflected there in a less pronounced degree, *i. e.*, a terrace or very small fold in the surface rocks may represent a much more pronounced folding in the Bend. However, it is almost certain that not all the terraces, "noses," etc., found in the upper rocks are indications of closing structure in the Bend.

(3) The possibility of favorable conditions in the Bend where the surficial indications of favorable structure are very small or wanting makes it unsafe to absolutely condemn any location, although it is fairly safe to consider a region of uniform normal dip in the surface rocks as improbable territory.

(4) Some geologists have worked out, by means of well-logs, a pronounced arch or geo-anticline in the Bend which extends northward from the Llano-Burnet mountains through Brown and Eastland counties, and they regard the territory along the crest of this arch as more favorable than that on its flanks. It should be said that not all who have studied the question agree on the presence of this arch.

(5) The lower beds of the Pennsylvanian rocks lying above the Bend thin out and disappear to the west, putting the Bend within reach of the drill much farther west than was thought to be the case before drilling was begun.

(6) The production in the Bend is spotted, probably on account of changes in the texture of the containing rocks within short distances.

The Permian rocks of Texas, like those of Kansas and Oklahoma, have not yielded any oil or gas (except possibly some of the shallow production at Electra-Petrolia) and their nature is such that it seems improbable that any will be found in them. This is the case in the Electra-Burkburnett-Petrolia district, where the surface rocks are Permian Redbeds, but where most of the production comes from the Pennsylvanian rocks.

In the Permian Redbeds area the structure is difficult to determine on account of the lenticular nature of the beds and their softness which makes good exposures rare.

High plains—The High plains are covered by Tertiary rocks, except for comparatively small areas of Triassic beds. The Tertiary deposits are of sub-aerial origin and cannot be considered as a source of oil or gas. They conceal any structures which may be present in the Permian rocks beneath. This makes prospecting a purely wildcat proposition, with the only chances for production in the Pennsylvanian rocks, which are deeply buried so that drilling is very expensive.

A gas well was brought in during the summer of 1918 north of Amarillo in the high plains region, but where the Tertiary rocks are removed, exposing the Permian in the valley of Canadian river. This production should, then, be considered as belonging to the Pennsylvanian-Permian area rather than to the High Plains.

Cordilleran region—Some of the rocks in the Cordilleran region in southern trans-Pecos Texas are of a character which makes them favorable for oil and gas. There is a thickness of thousands of feet of Pennsylvanian and Permian rocks, which is made up of shales, sandstones and limestones, and some shows of oil and gas have been reported from them. In the northern trans-Pecos the section is almost entirely limestone and is much less promising for oil or gas.

The structure of the whole region is very complex; the rocks are steeply folded and faulting is common. The rocks have been slightly metamorphosed by the folding they have undergone and since the folding took place at a comparatively remote period, it is improbable that the rocks now contain any large quantities of oil or gas.

The chances for oil or gas in the Cordilleran region seem to depend upon the finding of some areas where the folding is more moderate than in those so far studied and where the Pennsylvanian rocks are neither cut through by erosion nor too deeply buried beneath younger beds. While such areas may be found, the prospects do appear very bright at present.

Toyah basin—The Toyah basin is filled with Pleistocene or recent material, which completely prevents the determination of the character or position of the underlying rocks. Under these condi-

tions it can be considered only as very unfavorable territory for exploration.

Edwards plateau—The beds of the Comanchean system lie nearly level over the whole area of the Edwards plateau, and there is practically no chance of finding any quantity of oil or gas in these rocks. Wells which have been drilled in the area have reported showings of a heavy, black oil from the basal sands of the Comanchean.

Chances for production will depend on penetrating the buried rocks beneath the Comanchean. The character of these rocks is not definitely known, but judging from the evidence available, the rocks immediately beneath the Comanchean in the eastern part of the plateau are Pennsylvanian, probably corresponding to the Cisco and Canyon, and possibly the Strawn formations. The extent of the Bend series to the south of the Llano-Burnet mountains is unknown, but there is reason to believe that it does extend southward under the Edwards plateau and that it is within reach of the drill, at least in the eastern part of the area. Farther west the Permiam almost certainly comes in between the Pennsylvanian and the Comanchean, and the Bend, if present, is probably too deeply buried to be reached.

As has been said, the Comanchean rocks are nearly flat over most of the area. In the greater part the dip does not exceed five feet to the mile to the southeast. As the Balcones fault zone along the southeastern margin of the plateau is approached, the dip increases until it reaches 70 to 80 feet to the mile. In this belt there is considerable folding and also some faulting, due to the Balcones faulting and also to the great intrusions of Tertiary basalt and phonolite in the Uvalde region. In this belt of steeper dips the higher Comanchean formations are present so that the depth to the Pennsylvanian, if it be present, is much greater than it is farther west.

If favorable structures can be located in the lower Comanchean beds there still remains the question as to whether the structural conditions will coincide with those in the Pennsylvanian beds underneath, which are separated from the Comanchean by a pronounced unconformity. Nothing definite can be said on this point, but the writer believes that an anticlinal structure in the Comanchean would be indicative of a similar structure in the Pennsylvanian, and that the major features of the structures in the surface and sub-surface beds will coincide although the details of the structures should not be expected to do so.

As our knowledge of the area stands at present, the Edwards plateau is a region in which there is some chance of securing oil and gas, but the unconformity between the surface beds and the possibly productive beds and the absence of well defined structures in the surface beds makes it a territory which must be tested by pure

wild-catting, and the chances for a given wild-cat well to get production are necessarily small.

If good structures can be found in the surface beds, the chances are greatly increased, and worth taking, but are rather doubtful at best.

Black and Grand prairies—The portions of this area known as the West cross timbers and the Grand prairie, *i. e.*, the area of Comanchean rocks, gives little promise of producing oil or gas except from the Pennsylvanian rocks beneath the Comanchean. The Trinity sands are very near shore or sub-aerial deposits, and the higher formations are limestones and marly clays with very little or no bituminous material.

There is, of course, the chance of encountering oil or gas in the lower Pennsylvanian rocks under the Comanchean, but as any structures in the Pennsylvanian are effectually hidden by the Comanchean rocks, this resolves itself into rank wild-catting with small chances. The Comanchean rocks have a very gentle (about 20 to 30 feet per mile) and uniform dip toward the Gulf of Mexico. If reversals in this dip can be located, the locality is probably worth testing on the basis that this reversal is indicative of more pronounced and probably favorable structure in the Pennsylvanian rocks. So far as the writer's knowledge goes, no unquestionable structures of this kind have been reported from the Comanchean area.

The deposits of the Cretaceous, which underlie the Black prairie, are more bituminous and more promising for oil and gas than the Comanchean. Commercial deposits of oil and gas have been found in the Woodbine sand, the lowest formation, in the Caddo district in northwestern Louisiana and northeastern Texas and in the Nacatoch sand and other sand members of the upper part of the formation at Corsicana and in the Mexia-Groesbeck field.

In the Taylor and Navarro formations we have a great thickness of sands and clays spread over a large area. The deposits were all built up in fairly shallow water, for the most part, marine. It seems reasonable to suppose that there must have been many places during this deposition where the conditions were favorable for the preservation of sufficient organic material to produce oil and gas and also to favor their accumulation and retention. Also it seems probable that these conditions were largely local, both in time and space, and that the production will be found in isolated pools of rather small areal extent and that the productive sand will occur at different horizons.

The production so far found is closely related to anticlinal folding. The surface beds have a general easterly and southeasterly dip toward the Gulf of Mexico. The soft and unconsolidated beds weather to a deep soil and outcrops are few and short, so that it is

practically impossible to determine the details of the structure at most places in the Black prairie.

Under these conditions any wild-cat well in the region must be regarded as having some chances to open a new pool, although the great majority of them will undoubtedly be failures.

Gulf Coastal plain—The Tertiary sediments which underlie the Gulf Coastal plain are sands and clays deposited in shallow water, in large part non-marine. So far there has been no important production from these beds, and a study of their character makes it seem improbable that there will be. It is impossible to determine the structure, owing to lack of outcrops, and this makes the chances still more remote.

VI.

HISTORY OF THE OIL AND GAS INDUSTRY IN THE MID-CONTINENT FIELDS.

The history of the oil and gas industry in the Mid-Continent fields begins many years back, if all reported occurrences of either substance are considered, but it is only since about 1900 that any important production has been made. In the following paragraphs the development in each of the states is considered separately.

KANSAS*

Attempts to secure oil and gas were made in Kansas as early as 1860, but the methods used were not fitted to drill to sufficient depths, and it was not until 1882 that commercial quantities of either oil or gas were found. In that year gas with a small supply of dark, heavy oil was found at Paola, and gas alone in Wyandotte county. The field at Paola is still furnishing some gas, but the wells in Wyandotte county failed after about 15 years. Active development began about 1890; the Neodesha field was opened in 1893, and in the same year a good gas well opened up the field at Iola. Drilling was commenced about the same time at Humboldt, Chanute, Cherryvale, Coffeyville and Independence; but it was not until about 1900 that the greatest development began in these localities.

For several years the portion of the Mid-Continent field in Kansas was much more important than that in Indian Territory, but after about 1904 the principal development was on the south side of the line and the Territory surpassed Kansas in output. Kansas reached a máximum output in 1907, when two and one-half millions of barrels were produced, and declined rather rapidly from that time to 1910. For many years gas was a more important product in Kansas than in Oklahoma, and except in 1904, 1916 and 1917, the value of the gas was greater than that of the oil, reaching a maximum value of $8,293,846 in 1909, but declining to $3,340,025 in 1914; and then increasing to nearly $5,000,000 in 1916. From 1910 until 1914 there was a gradual increase in the production of oil, due to the

*The history of the early development in Kansas is taken principally from Vol. 9 of the University Geological Survey of Kansas. For the years since 1900 the statistics publishea by the United States Geological Survey and the oil journals have been used extensively.

rise in price, and beginning in 1914, a very rapid increase due to the development of the Butler county fields.

In 1904 the development of the southeastern Kansas pools continued rapidly. About 3,500 wells were drilled in Kansas and Indian Territory, of which by far the greater number were drilled in Kansas. The principal productive areas were in Allen, Neosho, Montgomery and Chautauqua counties. Early in the year there was pronounced activity in the Bolton and Wayside pools, near Independence, in Montgomery county. The oil development begun at Coffeyville in 1903, was actively continued and new production was found at Tyro, east of Caney, in the same county. Chautauqua county was also very active, the Spurlock-Blundell, Hoffman and Peru pools all being developed. New pools were developed near Erie, Neosho county (drilling began in 1903), and near Paola in Miami county. In the latter locality, paying production was found at a depth of about 350 feet. Late in the year the removal of leasing restrictions from the Cherokee lands in Indian Territory, transferred the interest to the south of the state line, and there was a pronounced falling of new drilling in Kansas. The production for the year in Kansas was 4,250,779 barrels, about three times that of Indian Territory and Oklahoma. This production greatly exceeded the capacity of the refineries, and the price for crude was subjected to successive reductions. The extreme variation of prices for the year was from 31 cents for the heavy oils (22 degrees-28 degrees B) to $1.38 for the lighter oils (32 degrees B).

In 1905, the low price of oil and the larger wells found in Indian Territory caused a marked reduction in activity in Kansas. The only developments of note were the continuation of the shallow sand development at Paola in Miami county and new shallow production at Rantoul in Franklin county, southwest of Paola. The sands at Rantoul vary in depth from 350 to 600 feet in depth. Chautauqua county was also active. The over-production continued throughout the year. The production from Kansas and Indian Territory was about 12,000,000 barrels, of which about one-third was produced by Kansas.

In 1906, there was very little new development in the oil industry in Kansas. There was some development near Paola, Osawatomie and Rantoul, and some in the Hoffman pool in Chautauqua county. Scattered wells were brought in over the entire area. The completion of gas pipe lines to Kansas City (Kansas), Topeka, Lawrence and Leavenworth and to the towns in the Joplin district in 1905, and to Atchison, Kansas City and St. Joseph, Missouri, early in 1906, stimulated the search for gas, and development was active in all the gas fields. The principal activity was near Independence, in Montgomery county.

In 1907 there was practically no new development in the oil industry in Kansas. The search for gas continued, and several valuable pools were opened. The principal ones were near Chanute, Fredonia and Hale. Some gas was found farther west at Elmdale, Augusta and Arkansas City. Gas found near Dexter consisted almost entirely of nitrogen.

The oil production for the year was 2,409,521 barrels, valued at $965,134. The gas production was over 80,000,000,000 cubic feet, with a value of $6,198,583.

Drilling was very quiet in 1908, and more old oil wells were abandoned than there were new ones drilled. No new oil pools were developed. The old gas fields were extended, but no new pools were found. The older pools in Allen, Neosho and Wilson counties began to decline perceptibly in pressure and production. The oil production amounted to 1,801,781 barrels, valued at $746,695, and the gas production to 80,740,000,000 cubic feet, valued at $7,691,587.

There was very little of note during 1909. The production of both oil and gas declined, and the price of oil remained very low. There were no important developments in the way of new oil or gas pools. The annulment, early in the year, of the law prohibiting the piping of gas from Oklahoma rendered the immense supplies of that state available to the Kansas companies, and there was less incentive for drilling in the older territory in Kansas. The quantity of oil produced was 1,263,764 barrels, with a value of $491,633, and the quantity of gas was 75,074,416,000 cubic feet, with a value of $8,293,846.

Conditions remained about the same during 1910, 1911, 1912, 1913 and 1914. During these years there was a further decline of oil production, in 1910, but beginning in 1911 there was a gradual increase in production with each year. This was due to the increasing price paid for crude, and resulted from more intensive drilling of the old pools and the discovery of small pools in what was already proven territory. No pools of any pronounced importance were discovered until the first well in the Augusta pool was brought in in June, 1914. This was the beginning of the development of the Butler county fields, which have completely overshadowed the other fields for the past few years.

From 1910 to 1914 the average initial production remained low, ranging from 10.8 barrels in 1914 to 22.3 barrels in 1910. Throughout the period Montgomery and Chautauqua counties led in production and in amount of development. At the end of 1914 Kansas had a total of 3,412 active oil wells.

The following tables give the production and value of petroleum for Kansas for the years 1909 to 1914 inclusive:

Year	Production in barrels	Value
1909	1,263,764	$ 491,633
1910	1,128,668	444,763
1911	1,278,819	608,756
1912	1,592,796	1,095,698
1913	2,375,029	2,248,283
1914	3,103,585	2,433,074

The prices for this period showed a continued rise, except during 1914, when the immense over-production of the Cushing field in Oklahoma caused a reduction in the price of crude.

The range in prices and the average price are shown in the following table:

Year	Low	High	Average
1910	$ .35	$ .42	$ .38¼*
1911	.42	.50	.45½
1912	.50	.83	.69
1913	.83	1.03	.95
1914	.55	1.05	.78

The history of the natural gas industry during the years under consideration was uneventful and in general was one of decrease of pressure and amount of gas produced. The supply became too small to supply the demand and great quantities of gas were supplied to Kansas towns from Oklahoma. The discovery of the Butler county and Cowley county fields in 1913 was the most important event.

The production and value of the natural gas in Kansas from 1910 to 1914 is given in the following table.

Year	Production in cubic feet	Value
1910	59,380,157,000	$7,755,367
1911	38,799,406,000	4,854,534
1912	28,068,370,000	4,264,706
1913	22,884,547,000	3,288,394
1914	22,627,507,000	3,340,025

In 1915 there was a slight reduction in the amount of petroleum produced, due to the low prices which were caused by the immense over-production in Oklahoma. Development continued active in the older pools, and the Augusta pool was developed to a slight extent, having 12 wells at the end of the year. The wells in this pool were the largest discovered in Kansas up to this time, one having an initial production of 1,500 barrels. Development at Eldorado, to the north of the Augusta field, began with the bringing in of a 100-barrel well in a shallow sand (about 600 feet). This pay was mudded off and the well drilled to a deeper pay at 2,460 feet. By the end of the year nine wells had been completed in the Eldorado field, all of which, except the first well drilled, were producing from the shallow sands.

*Above 30 degrees B.

There was renewed activity in the shallow pools near Paola and Rantoul in Miami county.

The marketed production for the year amounted to 2,823,487 barrels, with a value of $1,702,891. The price per barrel was 55 cents at the beginning of the year; by March it fell to 40 cents, where it remained until in August. During the last part of the year the price rose rapidly until it reached $1.12 per barrel in December. The average price for the year was 60 cents per barrel.

Due principally to the development of the Augusta field, there was a notable increase in the quantity of natural gas produced in 1915. The field at Augusta was discovered in 1913, and until 1915 was developed almost exclusively for gas. The gas sand is encountered at a depth of about 1,500 feet. The wells had an average initial capacity of 2,000,000 to 40,000,000 feet per day, with a rock pressure of 650 pounds.

Other development which tended to increase the production for the year were in Montgomery, Labette, Chautauqua, Woodson, Neosho and Greenwood counties. The amount of gas produced was estimated at 27,045,908,000 cubic feet, valued at $4,037,011.

During 1916, the Augusta and Eldorado fields were developed very rapidly, and the production of the state rose to 8,738,077 barrels, about three times that of the preceding year. The average price was $1.18 per barrel, more than twice that of 1915, so that the value of oil produced was $10,339,958, about six times that of 1915.

Although the interest and development centered in the Butler county fields, the older areas were actively developed and gave increased production. Several wild-cat wells in Greenwood, Sumner and Cowley counties gave showings of oil and attracted considerable interest, but none of these has so far led to the development of important pools. Late in the year the first well in the Towanda district, a western extension of the Eldorado field, was brought in, and drilling was very active the remainder of the year.

The production of natural gas amounted to 31,710,438,000 cubic feet, an increase of 17 per cent over that of 1915. The value of the gas produced was $4,855,389. The increase in production was due entirely to the activity in the Butler county fields.

During 1917 the development of the Towanda district was the principal item of interest. Many wells were drilled in this district, and they were of very large production, some of them producing from 12,000 to 20,000 barrels per day, the largest wells yet drilled in the Kansas or Oklahoma fields. Development was active in all the producing areas, but there was little of special interest outside the Butler county fields. The production amounted to practically 38,000,000 barrels, which was far in excess of any previous year.

The rapid development of the Butler county fields continued through 1918, and these pools furnished about 85 per cent of the production. The Towanda pool had some large producers, but by the end of the year the production of the older wells had declined greatly and the initial production of the newer wells was not sufficient to offset the decline. Late in the year production was found to the northwest of the Eldorado pool near Elbing, but the developments of 1919 indicate that the pool is a small one. This general area, however, had been expanded by the bringing in of a well farther to the north in Marion county. The total production for 1918 was in excess of 43,000,000 barrels.

OKLAHOMA.

The discovery of oil and gas in Kansas about 1882 excited the interest of the Five Civilized Tribes in Indian Territory, and in 1884 the Choctaw council passed an act forming the Choctaw Oil & Refining company. The Cherokees followed the example of the Choctaws almost immediately and passed a similar act. Both companies secured the co-operation of the Dr. H. W. Faucett of New York. A well was started in the Choctaw nation on Clear Boggy creek about fourteen miles west of Atoka, and one in the Cherokee nation, on Illinois river about twenty miles north of Tahlequah. The Cherokee council of 1885 repealed the charter of 1884 and operations on the well north of Tahlequah were stopped. The charter was reinstated in 1885, but financial support could not be obtained, and the proposition was not carried further. Drilling continued at the Choctaw well until Doctor Faucett's death in 1888, when it had reached a depth of 1,414 feet without encountering more than showings of oil and gas.

There was little further activity in Indian Territory until 1894, when the Cudahy Oil company secured a blanket lease on the Creek nation and had two wells drilled at Muskogee. Both showed good prospects, but there was no development until 1904, when title to the lands could be obtained.

The Cudahy Oil company also secured leases on about 200,000 acres in the vicinity of Bartlesville, and operations were started there. In 1896 the passage of the Curtis bill forced them to surrender all "unproved" lands, leaving them only the section on which Bartlesville now stands. Some development had been made at Chelsea prior to 1893, and the Cherokee Oil & Gas company had a large acreage leased. The Curtis bill caused the surrender of these leases and little was done in the Cherokee nation until 1904, when it became possible to get allottee's leases approved by the Department of the Interior.

Prior to 1904 tests had been made in the Osage nation as early as 1896. At this time all the lands of the nation were leased to

Edwin B. Foster, who secured a 5-barrel well at a depth of 1,100 feet, three miles south of Chautauqua Springs, Kan. A well was drilled to a depth of 2,575 feet at Eufaula in the Choctaw nation, with good showings of oil and gas at three horizons. A well at Red Fork opened the Red Fork-Tulsa district in 1901.

The principal development in Oklahoma fields began in 1904, and in the following paragraphs brief accounts of the development in each year from that time to the present is given. The total production and value of the output is given in this connection, but the detailed statistics are reserved for another section.

During the first six months of 1904, practically all the activity in the Indian Territory was confined to the Osage nation. The Indian Territory Oil & Illuminating company had a blanket lease on all Osage lands, and sublet the lands to the actual operators. The first well in the Cleveland pool in Pawnee county, Oklahoma Territory, was in September, and a great rush, both to the Oklahoma lands and to the Osage lands across the river, resulted. Some development was also carried on throughout the year in the vicinities of Muskogee, Chelsea, Red Fork and Bartlesville. The townsite pool at Muskogee was developed during this year. Later in the year the secretary of the interior began to confirm leases in the Cherokee nation. Drilling was immediately prosecuted with great activity, most of it being centered in the vicinity of Bartlesville, Chelsea and Alluwe, Lenapah and Dewey. At the close of November, Chelsea had about 96 producing wells; Red Fork, 50; Cleveland, 10; Muskogee, 35 or more; Bartlesville nearly 100, and other points in the Osage territory, 75 or 80 more. The Prairie Oil & Gas company was the principal purchaser of the product. The prices paid during the year varied from 31 cents for the heavy oils to 72 cents for the lighter oils. The production of Oklahoma and Indian Territories was 1,366,748 barrels, valued at approximately $1,325,750.

In 1905 there was no phenomenal new development, but the shallow field was extended north to Coody's Bluff, making a proven length of from 15 to 18 miles; the Bartlesville-Dewey pool was actively developed, especially along the Cherokee-Osage line south from Pawhuska, to the northwest and west from Bartlesville, and to the northwest of Dewey, where a new pool was developed; the Cleveland field was actively developed and some wells were had in the vicinity of Pawhuska in the western part of the Osage nation. The field near Wheeler, in the southern part of the state, was discovered in 1905. Prices for oil were very low in 1905, the price paid for the lighter grades of oil being 50 to 53 cents.

In 1906 active development continued in the regions already opened, especially in the shallow Coody's Bluff field and in the Bartlesville area. The remarkable feature of the year was the opening of the Glenn pool, a few miles southeast of Red Fork, in the early

part of the year. The first well was completed in December, 1905. By the end of 1906 a number of wells with an initial capacity of over 1,000 barrels had been drilled in and the limits of the pool had not been located. The total number of wells in the pool by the end of the year was about 110. Another remarkable pool was opened on section 27, east and a little south of Dewey and four miles east of Bartlesville. This area is only one mile across, but was developed very rapidly, and some wells of over 1,000 barrels capacity were brought in. The limits of the pool were soon defined, however, and the wells had settled down to about 300 barrels capacity by the end of the year. By the beginning of 1907 the field along the 96th meridian was pretty well outlined as extending from the Kansas line south almost to Tulsa, with a width of up to five miles or more. Several 1,000 barrel wells were brought in during 1906, most of them on the Osage side of the line, but some on the Cherokee or eastern side. These wells held up better than most of those in other parts of the field. The Morris pool in southeastern Okmulgee county was opened by a well southeast of town in the summer of 1906. As at previous times, the Prairie Oil & Gas company was the only important purchaser of the Oklahoma oils. The prices were very low. The average for the year was 47 cents for light oil and 31⅝ cents for heavy oil. Late in the year arrangements were made by two of the large interests of the gulf coast, the Texas company and the Gulf Pipe Line company, to build pipe lines into the Oklahoma field, and both lines were completed during the following year. As in 1905, the published statistics combine the production of Kansas and Oklahoma. The production of both states was about 16,500,000 barrels, and the value $7,250,000. The total production in Oklahoma and Indian Territories for the year was in the neighborhood of 7,000,000 barrels, and the value about $3,800,000. Neither the value nor the production can be stated accurately since the statistics for Kansas and Oklahoma were not kept separately.

In 1907 the Glenn pool continued its remarkable record of the previous year. At the beginning of 1907 this pool was showing a monthly production of 385,939 barrels. This increased rapidly until in the month of October it reached its maximum of 2,441,662 barrels. The production of the pool then began to decline, and by the end of the year had declined to the rate of six months before. Considerable development was also made in the Morris pool. Several good wells were brought in, but the field proved to be rather spotted. In the Cherokee district the development in the shallow field continued, and the production was maintained in spite of the fact that few new wells were brought in during the latter part of the year. The Dewey-Copan field was extended west by some wells of very large production. This extension was in the Osage lands. A good field was developed along Hogshooter creek, about 15 miles southeast of Bartles-

ville. The larger oil wells had a capacity of about 500 barrels per day, and the gas wells from five to fifteen million cubic feet per day. The Hogshooter field has since become more important on account of its gas than on account of its oil production. The prices for oil continued very low. There was very little variation through the year, the price for light oil ranging from 39 to 41 cents, and for the heavy oils from 26 to 28 cents. The production for the year was 44,300,149 barrels, with a value of $17,824,342.

Development work in 1908 was steady and the production of Oklahoma showed some increase over that of 1907, although there were no remarkable new finds. The decrease in production of the Glenn pool was checked by the drilling of new wells, the cleaning out and shooting of old wells and the finding at widely separated points of a deeper productive sand. A new pool of exceptionally high grade oil was found at Muskogee. Very late in the year a 1,400-barrel well was completed in the Morris pool, which led to considerable new drilling. Probably the principal development of the year was in the northern end of the shallow field (the Delaware-Childers pool). Production in the vicinity of Dewey and in the Osage generally declined. The price for light oil was uniformly 41 cents throughout the year, and for heavy oil remained very nearly 32 cents. The production was 45,798,765 barrels, valued at $17,694,843.

In 1909 a strong effort was made by the Producers' association to curtail the production on account of the extremely low prices prevailing, and there was only a slight increase over that of the previous year. The Glenn pool and the Osage showed a slight decline. The only new pool of importance was the Preston pool, five miles north of Okmulgee. A new pipe line, that of the Oklahoma Pipe Line company, to Baton Rouge, La., was assured. The price for light oil was 41 cents per barrel for the first half of the year and 35 cents the latter half. Heavy oil stood uniformly at 28 cents. The production was 47,859,218 barrels and valued at $17,428,990.

In 1910 there was a considerable increase in production over that of 1909. All the older fields were developed intensively and there was no marked decline in any of them. The principal new development was in Okmulgee county in the vicinity of Henryetta, and in Osage county at Osage Junction, across the Arkansas from the Cleveland pool. Gas was discovered at Poteau in the extreme eastern part of the state and south of the developed territory. The prices paid for oil ranged from 35 to 42 cents per barrel for light oil and from 28 to 42 cents for heavy oil. During the last part of the year the price for all grades of oil was made uniform and this practice has since been continued. The new pipe line to Baton Rouge was completed, which assisted in bettering trade conditions. The production was 52,028,718 barrels, valued at $19,922,660.

Development in 1911 was considerably retarded by the prolonged drouth which hindered both drilling and manufacturing enterprises, but in spite of this there was an increase in the producton over that of 1910. The principal factors of this increase in the production were the continued development of the pools near Osage Junction and in the Pawnee county pool and the increase in the Hogshooter field. The price of oil advanced from 44 to 50 cents per barrel and the rising prices had no small share in stimulating activity, so that the production was increased to 56,069,637 barrels, valued at $26,451,767.

For 1912 the most important feature of the industry was the increase in the price of oil, since this was mainly responsible for the increased activity throughout the field. During the year the price for oil increased from 50 to 83 cents per barrel. The operators responded actively to the increased prices for the product and drilling was prosecuted more rapidly than in any previous year. The old pools were extended and filled in and a great amount of wildcatting was done, much of which was successful in developing new territory. The most striking feature of the new development was the discovery of the Cushing pool in western Creek County. The first well was brought in during March and by the end of the year over 75 completions had been made with very few failures and over 100 rigs were centered in the field. The initial production of the wells was very high and the quality of the oil good. Other important developments were: the discovery of deeper sands in the Cleveland field, which had been producing from shallower sands for eight years, the eastward extension of the Glenn pool with wells of 300 to 500 barrels initial capacity, the opening of the Adair pool west of Nowata, the continued development of the Ponca City field in Kay County to the west of the main field, and the pronounced activity in Okmulgee County, carrying the field to the southeast. More good gassers were brought in in the Poteau field which had been opened during the previous year, and a new gas field opened in Coal County. The Wheeler field showed renewed activity, as did the field at Gotebo. A good gas well was brought in near Duncan in Stephens County, and there was some development at Loco, in the southeastern part of the same county. Some heavy oil was obtained in both localities. The State showed a decrease in production of about 4,000,000 barrels from that of 1911, the total production being 51,852,457 barrels. The average price was 67.4 cents, giving a total value of $34,957,612, an increase of $8,505,845 over 1911, in spite of the decease in production.

During 1913 the production of petroleum increased rapidly at an increasing rate. The increase was due principally to the more intensive development of the older pools. The most interesting feature was the development of the Cushing pool, which had been

discovered early in March, in 1912. The wells in the Layton and Wheeler sands were good producers, but declined rapidly so that the production varied greatly during the year. Beginning with a daily production of 11,000 barrels, the pool rose rapidly to 28,000 barrels per day by the end of February, and then declined to 16,000 barrels per day by June 10; increased to 30,000 barrels per day by September 1, and fluctuated between that figure and 23,000 barrels per day for the remainder of the year. In December the first gusher well in the Bartlesville sand was brought in, and the year ended in an excitement greater than that of the first discovery of the field. The first wells in the Healdton field, in western Carter County, were drilled in 1913 and produced great excitement. Record-breaking prices were paid for lease holdings. Drilling in the field was slow and the production was not important until 1914. Other developments of importance were the extensions of the Hogshooter and of the shallow fields, the further development of the Wicky pool near Mounds, the opening of the Booch sand pool in Okmulgee county and the bringing in of several good wells in the vicinity of Tulsa. The Inola and Owasso pools were opened. The price of crude advanced from 83 cents per barrel on January 1 to 88 cents on January 29, to 93 cents on July 7, to 98 cents on July 21, and to $1.03 on August 19. The production was 63,579,384 barrels, valued at $59,581,948.

In 1914 production increased rapidly, although field work slackened, during the latter part of the year, on account of the lessened price for crude, due to the over-production of the Cushing and Healdton fields and the disorganization of markets due to the European war. The Cushing field remained the center of interest throughout the year. Beginning with a production of about 25,000 barrels per day from the Layton and Wheeler sands, the production rose to more than 150,000 barrels per day by the end of June, and to more than 225,000 barrels by the end of the year. The phenomenal increase was due to the development of the Bartlesville sand. Development in the Healdton field was also very rapid and the production was near a million barrels for the year. The great flood of crude oil from Cushing and Healdton proved more than the market could carry, and vast quantities were placed in storage by the producers. The price declined from $1.05 per barrel early in the year to 75 cents per barrel by April 30, to 65 cents per barrel on September 12 and to 55 cents on September 22, where it remained for the rest of the year. The Healdton oil did not prove as good a refining oil as had been expected, and declined in price more rapidly than that of the main field. It reached a market price of 50 cents during April, and remained stationary to the end of the year. Besides the Cushing and Healdton developments there was little of great importance during the year. The Owasso and Inola pools proved to be small in area. The Newkirk field proved to be fairly productive, and a well between

Ponca City and Blackwell produced some excitement, but no pool was developed. The Booch sand pool in Okmulgee County was the leading development for the year outside of Cushing and Healdton. Six new refineries were built in the State and several small pipe lines from the Cushing and Healdton fields.

The over-production of 1914 continued into 1915, but the decline of the Cushing pool combined with the increasing consumption of gasoline reversed the situation and vast quantities of crude were taken from storage before the end of the year. The Cushing production reached 300,000 barrels per day in February and again in April. From then on the production declined steadily until the daily average for December was only slightly more than 100,000 barrels. Healdton continued active development throughout the year, although almost half of the production had to go into storage. There was little development in the way of new pools. The Fox or Shamrock pool, immediately south of the Cushing field, gave considerable production from the Layton and Bartlesville sands. The Boynton pool, in southwestern Muskogee county, reached a daily production of 8,000 barrels, but declined to about 5,000 barrels by the end of the year. This territory proved to be very "spotted." The Stone Bluff pool, in southwestern Wagoner county, was opened in October and by the end of the year was producing 5,000 barrels daily. A small pool at Vera, in Washington county, had several small producers with a total daily production of several hundred barrels. Deep production was found at Blackwell, but drilling is very difficult and there were very few completions by the end of the year, although some 20 wells were drilling to the deep sand. Wildcatting was active during the year. Some small gas and oil producers were brought in in Pontotoc county. Several wells were drilled in east-central Oklahoma, in McIntosh, Haskell, Coal, Hughes and Latimer counties. Some gas was found, but so far this section seems to be entirely without oil. The price of crude from the main field started at 55 cents per barrel, dropped to 45 cents on February 8 and to 40 cents on February 15, where it remained until August 2, when it rose to 50 cents, and then advanced to 60 cents on August 11, to 65 cents on August 19, to 75 cents on August 21, and to 80 cents on September 11, to 90 cents on November 13, to $1.00 on November 15, to $1.10 on December 13, and to $1.20 on December 14. The total production for the year is given as 115,919,541 barrels for the main field and 6,909,293 barrels for the Healdton field, making a total of 122,828,834 barrels.*

During 1916 Blackwell continued active; by March five wells had been completed, with a daily production of 2,000 barrels, 40 wells were drilling, and 75 rigs up or under construction. By the end of the year the production was estimated at 4,000 barrels per day.

*The Oil and Gas Journal gives the total production for Oklahoma as 117,910,444 barrels.

Near the end of the year the Garber-Covington pool was opened by a well drilled in Sec. 25, T. 22 N., R. 4 W., and several wells were started. The development at Billings began about the same time. The Tucker sand development in the Cushing field gave some very large wells, but the productive area in this sand proved to be small. The Southern or Shamrock extension of this field produced many large wells, but the field as a whole declined considerably. Other new development which attracted considerable attention was the opening of the Yale pool north of Cushing. The discovery of gas in a well at Maud, in Pottawatomie county, and at Perkins, Otoe and Ingalls, to the northwest of the Cushing field, and at Cement, in Caddo County. In the older parts of the field small pools were developed or the development continued at Bixby, Stone Bluff, Leonard, Biggs and Boynton. The principal new development in Osage County was near Hominy.

The prices per barrel paid for crude during the year were as follows:

Jan. 1st	$1.30	Aug. 1st	$1.25	Dec. 12th	$1.10
March 4th	1.40	Aug. 7th	1.15	Dec. 18th	1.20
March 11th	1.45	Aug. 12th	1.05	Dec. 23rd	1.30
March 14th	1.55	Aug. 15th	.95	Dec. 28th	1.40
July 24th	1.45	Aug. 26th	.90		
July 29th	1.35	Nov. 29th	1.00		

*The production for 1916 was 106,190,240 barrels.

There were practically no new developments in Oklahoma during 1917. On account of the high price of crude, all the older pools were quite active, and occasionally wells of considerable size were brought in. Garber and Billings were developed actively and the presence of considerable pools of high-grade oil was fully demonstrated. The Yale and Quay pools furnished many wells, which, while not phenomenal producers, held up well. Gas in large quantities was discovered at Morrison, in eastern Noble County, and also at Walter, in Cotton County. Sufficient drilling was done in the latter locality to prove a considerable gas field and two oil wells were brought in. The Bixby, Leonard, Wicey, Stone Bluff and Boynton pools were pretty well defined by the end of 1916 and contributed little of interest during 1917, although good wells were brought in occasionally. On the whole, the year was marked by intensive development of the older pools, with Garber and Billings furnishing most of the interest in new territory.

The price changes for the year were as follows:

January 3rd	$1.50
January 6th	1.60
January 12th	1.70
August 15th	1.90
August 18th	2.00

*Oil and Gas Journal.

*The production for the year was 97,674,356 barrels, a decrease of about 8,500,000 from that of 1916.

During 1918 development was very active in Oklahoma, but the results were not particularly encouraging. The older pools continued to decline in production and no new pools of importance were discovered. So, while the number of wells drilled was greater than in any previous year, the production was nearly 13,000,000 barrels less than in 1917, amounting to about 85,000,000 barrels. Wildcatting was most active in southern Oklahoma, particularly in Stephens and Cotton counties, and some encouraging showings were made, but it is not possible at this time to make any accurate forecast of the final results.

TEXAS.

In the following summary of the history of the development of the oil and gas industry of Texas, only those which are part of the Mid-continent field are noted. These fields are grouped as the "Stratum Division" of the Texas pools by the United States Geological survey. The salt dome fields of the Gulf Cóast are not included in the discussion.

The first commercial discovery of oil in the portion of Texas here considered was at **Corsicana, Navarro County, in 1895, and until 1900 this pool was the only producer in northern Texas. It was developed rapidly and by the end of 1899 there had been drilled 642 wells of which 511 were oil wells, 13 gas wells and 118 dry holes. The maximum output was in 1900, when 829,000 barrels were produced.

In 1900 the Powell district, about five miles east of Corsicana, was opened and produced about 6,000 barrels in 1906, since which time it has declined to 215,729 barrels.

In 1910 oil was found at Petrolia, Clay County, in shallow wells drilled for water. The first shipments were made in 1904. The first deep drilling which opened the gas sands was in 1907.

Oil had been known in shallow wells at Electra, Wichita County, for several years, but the first successful deep well was drilled in 1910. This well ran wild for some time and when finally controlled produced 300 barrels per day.

The Burkburnett pool, in Wichita County, was opened in 1912. The three fields just named are known collectively as the Electra-Petrolia district, have been the most important producers in the Texas portion of the Mid-continent field, and the history of their production will be noted more fully in a succeeding section.

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*Oil and Gas Journal.

**Matson, G. C., and Hopkins, O. B., The Corsicana oil and gas field, Texas; Bull. U. S. Geol. Survey. No. 661, p. 213.

A westward extension of the Caddo field of Louisiana was developed in 1910. The Moran pool was opened in 1913, the Strawn and Thrall pools in 1914, the Ranger and Brownwood shallow pool in 1917.

For 1918 the principal features were the rapid development of the Ranger pool, the discovery of small production in Coleman County, the bringing in of the Duke pool in Comanche County, and the new Burkburnet pool in Wichita County. These and other developments of the year are noted in detail under the descriptions of the fields.

The statistics for production for Texas are given in the tables at the end of this section.

Louisiana.

The pools in Louisiana which are included in the Mid-continent field are situated in the northwestern part of the State. The two principal pools are known as the Caddo and the DeSoto-Red River.

The Caddo pool was discovered in 1904 and the development has continued to the present. There have been many fluctuations in the activity due to the varying prices for oil and the bringing in of new areas of production from time to time. The district is notable for its variation in daily production, which is on account of the very large initial production of the wells and their rapid decline.

The DeSoto Parish development began in 1912, and that in Red River Parish in 1914. The Crichton pool, the most important in this district, was opened in 1915.

Outside the main areas there has been considerable gas developed at Monroe, and, early in 1919, an oil well was brought in near Homer, in Claibourne Parish, to the east of the main fields. There has also been great activity in the Bull Bayou district.

TABLE SHOWING MARKETED PRODUCTION AND VALUE FOR THE MID-CONTINENT FIELD, BY STATES, 1905-1918.

	KANSAS		OKLAHOMA		NORTH TEXAS		NORTH LOUISIANA	
Year	Production	Value	Production	Value	Production	Value	Production	Value
1905	3,750,250	$ 2,250,150	6,466,200	$ 3,524,122	520,282	$ 361,604	---------	$ ---------
1906	3,627,375	1,367,224	18,500,000	8,000,000	1,117,905	740,542	3,358	2,183
1907	2,409,521	965,134	44,300,149	17,824,342	912,618	721,577	50,000	38,863
1908	1,801,781	746,695	45,798,765	17,694,843	723,264	479,072	499,937	214,048
1909	1,263,764	491,633	47,859,218	17,428,990	681,940	393,732	1,028,818	549,081
1910	1,128,668	432,638	52,028,718	19,922,660	969,403	505,396	5,090,793	2,395,191
1911	1,278,819	608,756	56,069,677	26,451,767	2,251,193	1,213,960	6,995,828	4,018,792
1912	1,592,796	1,095,695	51,852,457	34,957,612	5,275,529	4,112,826	7,177,949	5,710,515
1913	2,375,029	2,248,283	63,579,384	59,581,948	9,184,252	9,125,185	9,781,560	10,074,307
1914	3,103,585	2,433,074	73,631,724	57,253,187	9,451,622	7,778,955	11,808,469	11,206,686
1915	2,823,487	1,702,891	98,915,243	56,706,133	7,473,553	4,656,934	15,082,034	9,365,343
1916	8,738,077	10,339,958	107,071,715	128,463,805	9,303,005	11,834,973	11,821,642	12,178,262
*1917	24,253,869	------	97,674,356	------	10,930,507	------	8,648,025	------
*1918	43,253,470	------	84,950,291	------	20,384,915	------	14,133,545	------

*Total production. Oil and Gas Journal.

TABLE SHOWING WELL COMPLETIONS IN THE MID-CONTINENT FIELD, BY STATES, 1905-1918.

	KANSAS				OKLAHOMA				NORTH TEXAS				NORTH LOUISIANA			
Year	Total	Oil	Dry	Gas	Total	Oil	Dry	Gas	Total	Oil	Dry	Gas	Total	Oil	Dry	Gas
1905	1,277	817	211	249	2,510	2,059	353	98	---	--	--	--	--	--	--	--
1906	779	366	151	262	2,779	2,268	348	163	---	--	--	--	2	1	1	--
1907	368	68	64	236	3,956	3,490	318	148	173	106	67	--	23	8	4	11
1908	566	72	127	367	2,844	2,458	284	102	81	57	24	--	58	43	9	6
1909	558	69	106	383	3,279	2,742	380	157	175	116	45	11	121	69	33	19
1910	428	85	82	261	3,777	3,188	408	181	190	108	66	16	226	124	54	48
1911	418	172	96	150	4,087	3,294	304	489	126	84	38	4	341	246	63	32
1912	949	536	160	253	5,993	4,712	843	438	434	299	124	11	353	239	62	52
1913	2,016	1,422	260	334	8,851	6,965	1,308	578	799	581	208	90	518	356	92	70
1914	2,340	1,753	270	317	8,292	6,410	1,343	539	744	497	221	26	445	302	91	52
1915	1,088	610	147	331	4,624	3,397	885	342	528	307	198	23	464	349	89	26
1916	3,624	3,142	370	112	4,383	6,086	1,120	379	683	500	115	38	520	324	141	55
*1917	3,469	2,736	559	174	6,676	4,987	1,292	397	1,020	740	262	18	463	334	83	46
*1918	4,671	3,474	925	272	8,367	5,505	2,109	753	1,225	904	298	23	523	360	106	57

*Oil and Gas Journal.

VII.

DESCRIPTION OF THE OIL AND GAS FIELDS.

OIL AND GAS FIELDS OF KANSAS.

The oil and gas development of Kansas is confined to a relatively small area in the southeastern portion of the State. The counties which may be considered as lying in the oil and gas fields are, beginning at the northeast, Franklin, Miami, Linn, Bourbon, Allen, Woodson, Neosho, Wilson, Greenwood, Butler, Elk, Labette, Montgomery, Chautauqua, Cowley and Sumner.

The principal production is divided into an eastern and a western district. The eastern district lies principally in Allen, Woodson, Wilson, Neosho, Labette, Montgomery and Chautauqua counties, and the western district in western Butler and Cowley. The two districts are separated by a comparatively barren belt, including Greenwood, most of Elk, and the eastern parts of Butler and Cowley counties. The development in Franklin and Miami counties is separated from the main eastern district by an almost barren belt, including Anderson and Linn counties.

The main eastern district is continuous with the Bartlesville district in Oklahoma, but is characterized by smaller wells, both of oil and gas, and in general by a lower grade of oil. The producing sands in the eastern part of the district are members of the Cherokee shale.

The Butler county fields are the important part of the western district, since Cowley and Sumner counties have produced very little oil and only moderate amounts of gas. The oil in the western district is of considerably better grade than that of the eastern district, and the average initial production of the wells is very much greater. The producing sands are at a considerably higher horizon than those farther east. The structural conditions are also different and the analogies of this district are rather with the Kay county and the Billings and Garber fields in Oklahoma than with the eastern Kansas district.

In general the accumulation in the pools in the eastern district does not seem to depend much on structural conditions but more on the porosity and thickness of the sands and, probably, on the organic content of the shales with which they are associated.

The belt of production is one of minor folding, but with few or no pronounced closing structures. It may be said that where

undoubted favorable structural is shown on the surface that production is almost certain to be found but that the production is not restricted to such localities occurring also where the surface dip is normal and even in small synclinal folds.

In the western district the important pools are located on well defined anticlines. There is considerable variation in detail between the surface structure and that of the producing sands, and the areas of greatest production do not coincide with what would be regarded as the most favorable from the surface structural conditions. However, there can be no doubt that the anticlinal structure is one of the controlling elements in the accumulation of the field as a whole.

In the following paragraphs the Kansas development is discussed under the different counties in which it occurs.

Eastern District.

Franklin and Miami Counties.

The oil and gas development in Franklin and Miami counties is continuous, lying in the western part of Miami and the eastern part of Franklin. The productive area is shown in fig. 62. The area is the northernmost extension of the eastern district and is separated from the main part of the district by a distance of about 50 miles.

The surface rocks belong to the lower part of the Pennsylvanian system. The Pleasanton shale, the highest member of the Marmaton formation outcrops in the southeastern corner of Miami

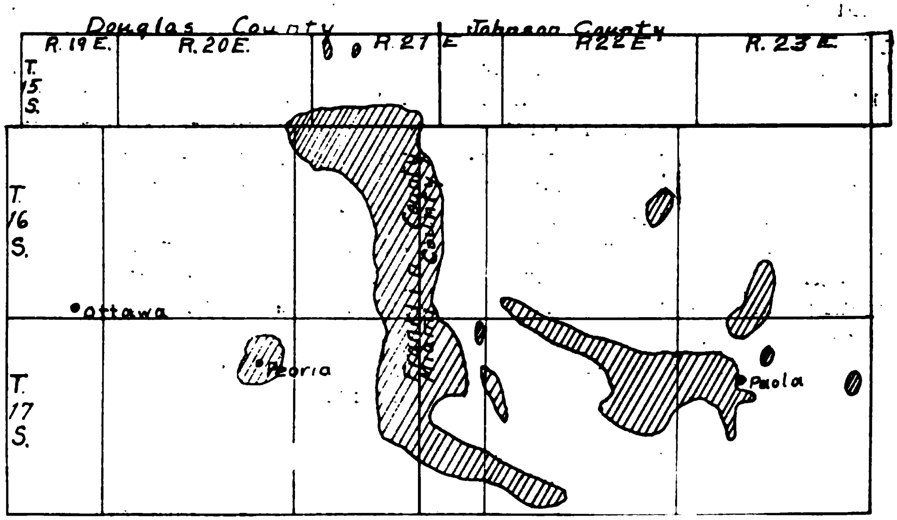

Fig. 62.—Map showing producing areas in Franklin and Miami counties.

county. Toward the northwest successively higher formations are encountered. The Kansas City formation covers nearly all the southeastern half of Miami county; the Lansing, the northwestern half of Miami and southeastern part of Franklin; and the Douglas formation the northwestern part of Franklin.

The general dip is about 20 feet to the mile to the northwest. Some small variations in the normal dip are known to occur but their relationship to the accumulation has not been determined.

The production is in the northwestern fourth of Miami county and in an adjoining belt about five miles wide in Franklin county. Practically all the production is in Townships 16 and 17, Ranges 21, 22 and 23 east, but only a part of these six townships are productive.

The Miami county development is known as the Paola pool. Most of the productive wells in the vicinity of Paola are in secs. 16, 17, 18 and 19, T. 17 S., R. 23 E. From this locality a narrow production belt extends northwest across the northwestern part of T. 17 S., R. 22 E., and into the southwestern corner of T. 16 S., R. 22 E., near Whittaker. A short distance to the southwest of this belt is another group of wells in secs. 22, 23, 24 and 26, in T. 17 S., R. 22 E. Other productive areas lie about three miles east of north from Paola in secs. 33 and 34, T. 16 S., R. 23 E., and two adjoining sections to the south, and in the extreme southwestern part of T. 17 S., R. 22 E.

The principal development in Franklin county is known as the Rantoul pool. It includes a belt a little more than a mile wide just west of the Franklin-Miami county line, extending from near Rantoul northward for six miles. There is scattered development over nearly all the northwestern part of T. 16 S., R. 21 E.

By far the greater part of the wells produce oil but there are gas wells scattered through the field and groups of gas wells in some localities.

The principal gas areas are (1) about three miles west of Paola in secs. 14, 15 and 23, T. 17 S., R. 22 E: (2) a group of wells immediately southeast of Rantoul; (3) in secs. 34, T. 16 S., R. 21 E., and the adjoining section to the south; and (4) in the vicinity of Peoria in sec. 12, T. 17 S., R. 20 E.

The development in Franklin and Miami counties dates back to about 1900. There was considerable activity during 1904, 1905 and 1906, but during the following period of low prices there was very little drilling. With the increased price for oil, the area took on a new lease of life in 1914, 1915 and 1916, but was checked in 1917 and 1918 by the transfer of attention to the more prolific Butler county fields.

The wells in this area have never been phenomenal producers. Initial productions of as high as 250 barrels per day have been recorded but 40 to 50 barrels is considered a good well. The wells

decline rather slowly to a settled production of 4 to 5 barrels. The gas wells are rather small, most of them showing an initial capacity of less than a million cubic feet per day. The territory is spotted and the percentage of dry holes is high, averaging 15 per cent for the two counties.

The production comes from different horizons. Productive sands are recorded at depths ranging from less than 300 to more than 900 feet, but the bulk of the production comes from between 400 and 600 feet. The thickness of the sands also varies widely, ranging from only a few feet to 50 feet. Some of the shallow production comes from the lower members of the Marmaton formation but the greater part comes from the sand lenses in the Cherokee shale. The Mississippi lime is penetrated at 1,000 to 1,200 feet below the surface.

RECORD OF WELLS COMPLETED IN FRANKLIN AND MIAMI COUNTIES 1904—1916.

Year	Oil	Gas	Dry	Total
1904	84	--	13	97
1905	252	21	36	309
1906	88	6	16	110
1907	14	4	8	26
1908	1	6	1	8
1909	--	6	1	7
1910	1	2	--	3
1911				
1912	18	--	--	18
1913	54	1	3	58
1914	294	45	72	411
1915	104	25	37	166
1916	451	5	70	526

The total and average initial productions for the two counties are given in the following table:

	1912		1913		1914		1915		1916	
Year	Ttl.	Avge.	Ttl.	Avge.	Ttl.	Avge.	Ttl.	Avge.	Ttl.	Avge.
Franklin County	155	8.6	748	13.9	1,360	8.3	620	8.7	2,666	11.4
Miami County	--	--	--	---	920	7.0	462	14.0	4,199	19.4

Linn and Anderson counties adjoin Miami and Franklin counties on the south and the geological conditions are almost precisely similar. These two counties lie in the belt included in the eastern district and there is no apparent reason why they should not be productive of oil and gas. However, there has been no development of any importance although many test wells have been drilled. A small amount of oil has been found near Mound City in Linn county, and there are several old gas wells, most of which have been abandoned, in Anderson county. Some wells in both counties have shown small amounts of oil, but there is almost no commercial production. The depths to the horizons in the Cherokee shale, which are productive to the south, vary from about 300 feet in the southeastern part of Linn county to about 1,000 feet in the northwestern part of Anderson county.

The most important recent development in Linn county has been the discovery of a fair grade of oil near the towns of Parker and Beagle. There are at Parker some 25 wells with an average daily production of 10 barrels per well, at a depth of 600 feet. The wells at Beagle produce at about the same rate at a depth of 500 feet.

The most important development in 1917-18 in Anderson county was the discovery in sec. 11, T. 20 S., R. 20 E., of a good grade of oil at 650 feet. These wells on the Poss farm had an initial production of 100-150 barrels and still produce at the rate of from 15 to 20 barrels. The discovery was limited, however, to 6 wells and, while another well at a like depth has recently been drilled in sec. 14, it is likely that the field will here prove very limited.

Allen County.

The rocks of Allen county belong to the Kansas City, Lansing and Douglas formations. As is the case in the whole district, the rocks dip gently to the northwest.

The production of oil and gas in Allen county dates back several years, the gas pool at Iola being one of the early developments in Kansas.

The development is well scattered over the county but the important production can be grouped into three pools, the Iola, the Moran and the Humboldt. The producing areas are shown in fig. 63.

The Iola pool may be considered as including the important gas development which centers about Iola. It is an irregular shaped area extending from the south side of T. 25 S., R. 17 E., northeastward to the vicinity of Carlyle, a distance of about 15 miles. For most of the distance the producing area is about 5 miles wide but near Iola and LaHarpe it expands to about 10 miles in width. Dry holes in the southwest part of T. 25 S., R. 18 E., practically divide the pool into two parts. The pool is primarily a gas producer. A few oil wells are scattered through the pool, most of which lie within three or four miles to the west and southwest of Iola. The largest recorded capacities of the gas wells are about 15,000,000 cubic feet per day, but most of the wells are much smaller. The gas from this pool has been the cause of the location of large zinc smelters at Iola.

The development near Moran, in the eastern part of the county is principally of oil. One group of wells lies from 2 to 4 miles east of Moran and includes about 6 square miles in the south-central part of T. 24 S., R. 21 E., and one square mile in the township to the south. Another group extends west and southwest of Moran for about 6 miles. This group is practically continuous with the Iola pool to the west. A group of gas wells lies from 1 to 3 miles south

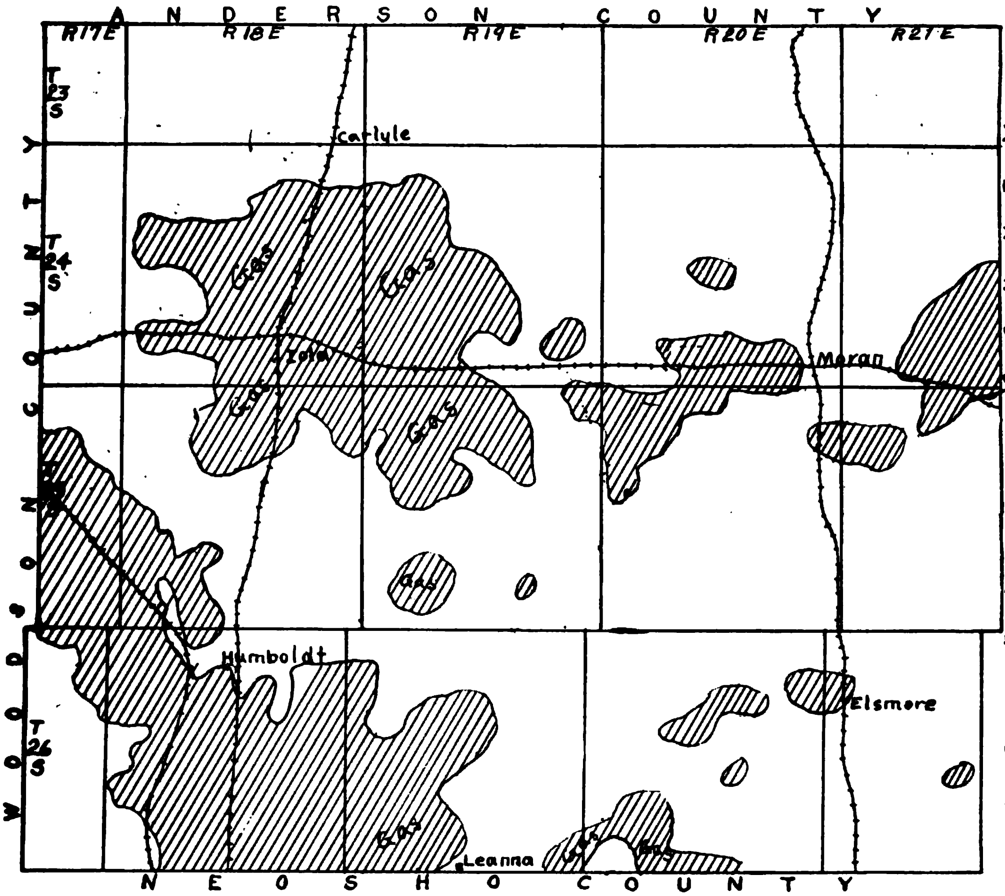

Fig. 63.—Map showing producing areas in Allen county.

of Moran. The Humboldt pool is in the southwestern part of the county, including all of T. 26 S., R. 18 E., and extending into the adjoining townships. It is continuous with the Iola gas pool to the north and the Chanute oil pool to the south. Most of the wells are oil producers, but there are gas wells scattered through the pool and a large group of them in the southwestern part of the pool.

In addition to the three pools noticed above there is considerable development in a belt extending diagonally across T. 26 S., R. 19 E., from the vicinity of Elsmore southwestward to the vicinity of Leanna. This development is principally gas with a few oil wells in the middle part of the belt.

The oil wells of Allen county are of small initial production, very few producing over 100 barrels per day and the most of them being much smaller. They hold up well, however, and this fact coupled with the shallow drilling has made the field a profitable

one. The depth of the wells ranges from about 650 to about 900 feet.

There ae at present some 16 wells west of Savonberg, sec. 29, T. 26 S., R. 20 E. These wells have at present a production which gauges 45 barrels daily.

WELL RECORD FOR ALLEN COUNTY, 1904-1916.

Year	Wells Completed—Oil	Gas	Dry	Total	Initial Production—Total	Avge.
1904	187	--	63	450	---	---
1905	7	3	3	13	---	---
1906	--	2	--	2	---	---
1907	6	37	2	45	---	---
1908	22	133	37	192	---	---
1909	16	100	35	151	---	---
1910	13	51	14	78	---	---
1911	30	19	10	59	353	11.8
1912	50	2	6	58	632	12.6
1913	154	6	11	171	2,960	19.2
1914	175	8	10	193	1,896	10.8
1915	49	13	3	65	500	10.2
1916	14	6	6	326	3,771	12.0

Neosho County.

Neosho county lies directly south of Allen county and the general conditions are similar to those just described, except that the rocks in southeastern Neosho county are older than those exposed in Allen county and those in northwestern Allen county are younger than any in Neosho.

The principal oil and gas field is known as the Chanute pool and is the continuation of the Humboldt pool of Allen county. The principal oil production is in a belt in the northwestern part of the county, extending from the Neosho-Allen county line southeastward past Chanute to the vicinity of Erie. Important gas producing areas with scattered oil wells lie northeast and southwest of the main oil belt. Gas wells are distributed irregularly through the oil producing district. There are two groups of oil wells in the vicinity of Thayer in the southwestern part of the county. The producing areas are shown in fig. 64.

The oil development of Neosho county dates back to 1903 when the first big oil well was brought in. The wells are generally small, a few wells have had initial productions of 250 barrels or more per day but the majority have had less than 100 barrels per day. The production settles to 5 to 10 barrels per day per well within a few months and continues at this rate for several years before the wells are exhausted.

The producing horizons and the depths to production are practically the same as for Allen county.

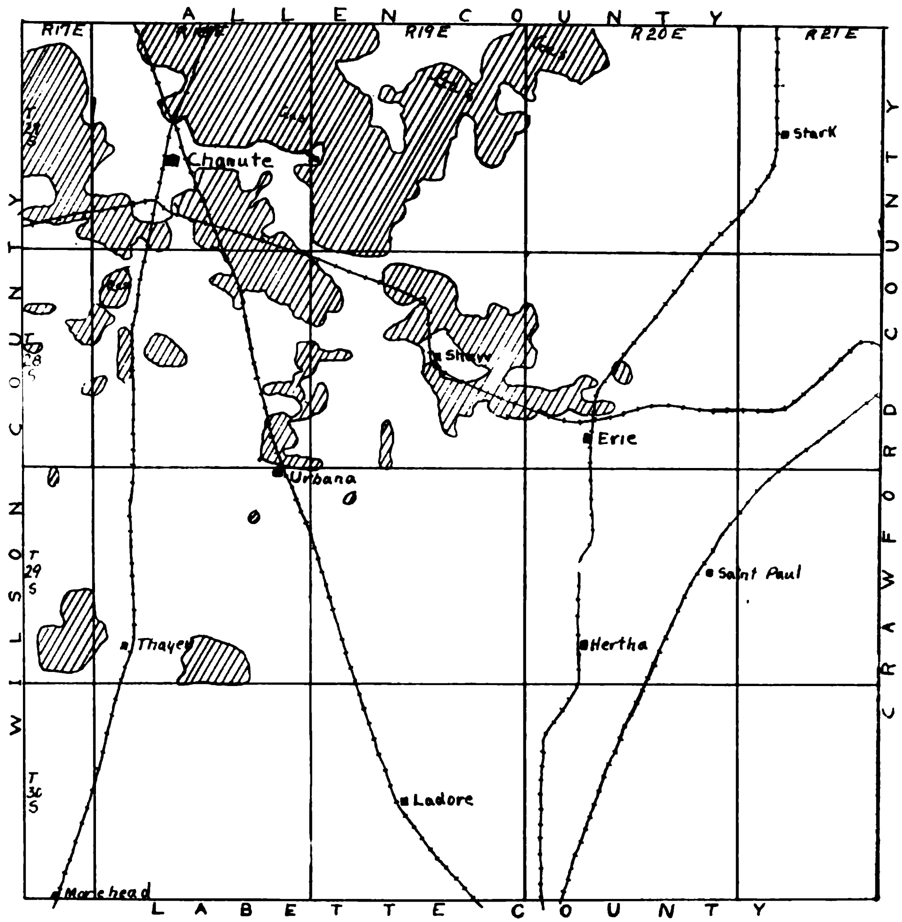

Fig. 64—Map showing producing areas in Neosho county.

WELL RECORD FOR NEOSHO COUNTY, 1904-1916.

Year	Wells Completed				Initial Production	
	Oil	Gas	Dry	Total	Total	Avge.
1904	454	--	65	519	---	---
1905	97	27	31	155	---	---
1906	68	6	36	165	---	---
1907	7	87	18	112	---	---
1908	30	54	31	118	---	---
1909	18	65	17	100	---	---
1910	9	61	17	87	---	---
1911	16	21	22	59	208	13.0
1912	62	30	23	115	693	11.2
1913	257	32	27	316	5,168	20.1
1914	221	23	19	263	2,414	10.9
1915	92	43	9	144	1,182	12.8
1916	237	6	8	251	---	---

Woodson County.

The rocks of Woodson county belong to the Douglas and Shawnee formations, with a small area of the Lansing formation

in the southeastern corner. As in the rest of the district, the normal dip is to the northwest, with small local variations. The top of the Cherokee shales is reached at a depth of about 1,000 feet and granite was reported in a well near Yates Center at 2,550 feet.

The development of Woodson county has been very slow and the production, both of oil and gas, is small.

The principal productive area is in the southeastern part of the county and is the continuation of the Humboldt pool in Allen county to the southeast. The production in this area is scattered. The wells are mostly oil wells with a few gas wells in T. 26 S., R. 17 E. The other development consists of a few oil and gas wells within a radius of about two miles from Yates Center, a small group of oil wells about a mile west of Vernon, and a larger group near Neosho Falls in the northeastern corner of the county. Many of the older wells have been abandoned.

While several wild cat wells have been drilled in the county, much of the area, especially in the western part has not been thoroughly tested and the county may become more important as a producer in the future than it has been in the past.

Recent development in Woodson county has centered in the Vernon field and south of Yates Center. The oil at Vernon is a heavy variety with a settled production of 2 to 5 barrels per well daily.

South of Yates Center in secs. 22, 23, 26, 27, T. 25 S., R. 15 E., a small gas field has been discovered at a depth of approximately 1,100 feet. These wells later produce a heavy oil in small quantities.

WELL RECORD FOR WOODSON COUNTY, 1904-1916.

Year	Wells Completed Oil	Gas	Dry	Total
1904	20	--	4	24
1909		2	-	2
1912	1	3	3	7
1913	2	--	3	5
1914	2	--	2	4
1915		23	2	25

Wilson County.

Wilson county lies immediately south of Woodson county and the general conditions are similar. The surface rocks belong to the Kansas City, Lansing and Douglas formations. The depths to the producing sands vary from about 700 to a little over 1,000 feet.

The production of oil and gas, however, is much more important in Wilson than in Woodson county. The development began very early with the opening of the gas field near Neodesha in 1893. The company which did the early work in this field was later reorganized as the Prairie Oil and Gas company, which has become one of the principal producing and transporting companies in the Mid-Continent field. The later development has followed the fluc-

tuations noted in the general historical discussion of the Kansas field, being governed principally by the variations in the price of oil.

Throughout the history of the development, gas has been more important than oil in Wilson county. The gas wells far outnumber the oil wells and the value of gas produced has been much greater than that of the oil. The abundant supply of gas has led to the establishment of important manufacturing industries at Neodesha and Fredonia.

The gas production is scattered in a broad belt including practically the eastern two-thirds of the county and connecting in a general way the Humboldt and Chanute pools to the northeast with the Montgomery county pools to the south. Within this area, the wells are clustered more thickly in some localities than in others,

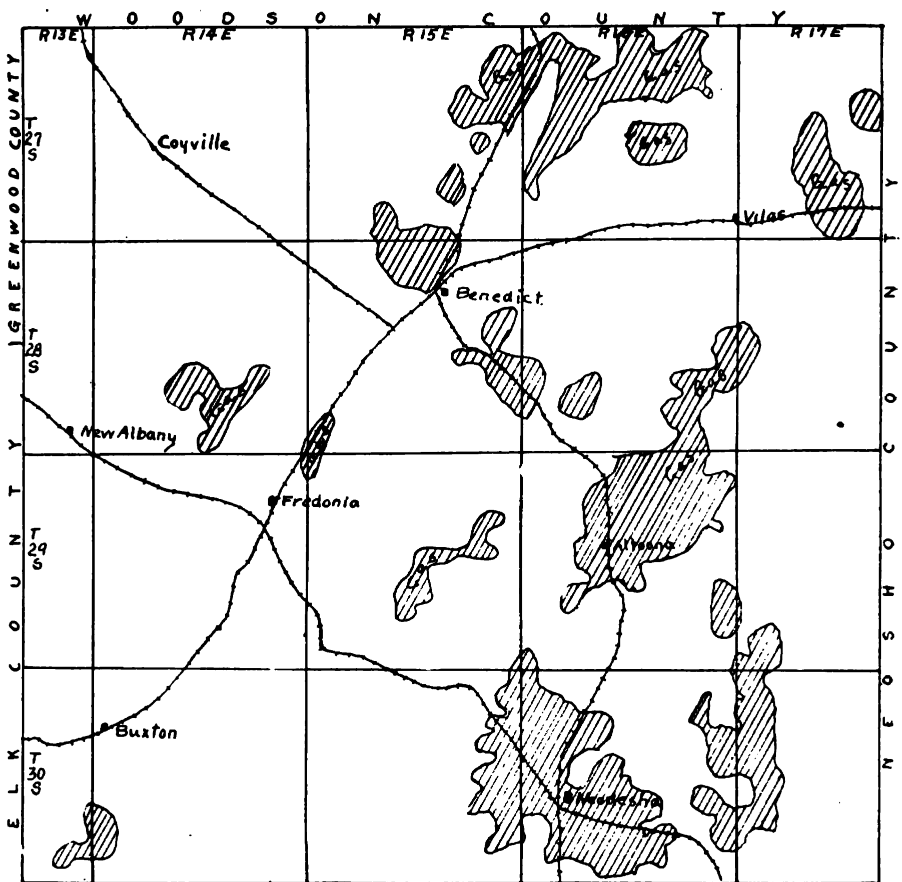

Fig. 65.—Map showing producing areas in Wilson county.

but they are not grouped into distinct pools. Oil wells occur at intervals throughout the area and in considerable groups in the vicinity of Neodesha, near Altoona, and in a belt extending northeastward from Benedict to the north line of the county. The producing areas are shown on the sketch map (fig. 65.)

WELL RECORD FOR WILSON COUNTY, 1904-1916.

Year	Wells Completed—Oil	Gas	Dry	Total	Initial Production—Total	Avge.
1904	70	--	41	211	---	---
1905	36	24	16	76	---	---
1906	--	89	24	113	---	---
1907	-	47	10	57	---	---
1908	--	60	21	87	---	---
1909	--	89	24	113	---	---
1910	1	80	27	108	---	---
1911	2	65	27	94	35	17.5
1912	18	86	52	156	255	14.2
1913	40	54	45	139	342	8.6
1914	37	12	20	59	268	9.9
1915	6	13	4	23	35	5.8
1916	63	3	2	68	365	3.1

Montgomery County.

The surface rocks of Montgomery county belong to the Marmaton, Kansas City, Lansing and Douglas formations. The Marmaton occupies a small area in the southeastern part of the county; the Kansas City most of the eastern part; the Lansing, a broad belt west of the middle; and the Douglas, a belt along the western border. The main productive horizons are in the Cherokee formation, the top of which is reached at depths ranging from about 400 feet in the southeastern part of the county to more than 1,000 feet in the northwestern part.

Production of oil and gas is scattered over almost the entire county. Every congressional township has had some productive wells. However, the principal productive area is a belt about 12 miles wide extending diagonally across the county in a northeast-southwest direction. The development in this belt is practically continuous and cannot be sharply differentiated into pools. However, the oil wells are grouped to some extent and the groups are spoken of as "pools." The principal groups of oil wells in the main productive belt are (1) the Cherryvale, lying northwest of the town; (2) the Independence, lying about 4 miles southeast of Independence; (3) the Bolton, a rectangular block extending about 3 miles east and 4 miles north from Bolton; (4) the Wayside, an irregular shaped area centering at Wayside; and (5) the Caney, extending eastward from Caney along the south line of the county. Smaller groups of oil wells lie about mid-way between Dearing and Jefferson, near Larimer, and along the north line of the county northwest of the Cherryvale pool. Gas wells are found in all parts of the county, but the great gas producing area is a belt extending south from In-

dependence to the south line of the county and varying in width from 2 or 3 to 9 or 10 miles.

Besides the development in the main belt there is oil development in the southeastern part of the county and near Elk City in the northwestern part. The producing areas are shown in fig. 66.

The history of the Montgomery county field began in 1893 when the first gas was discovered. Oil production began about 1902 and about the same time the gas production was greatly increased by the discovery of larger wells than had been brought in hitherto.

Following the discovery of oil the development of the county was very rapid and most of the pools had a maximum of activity

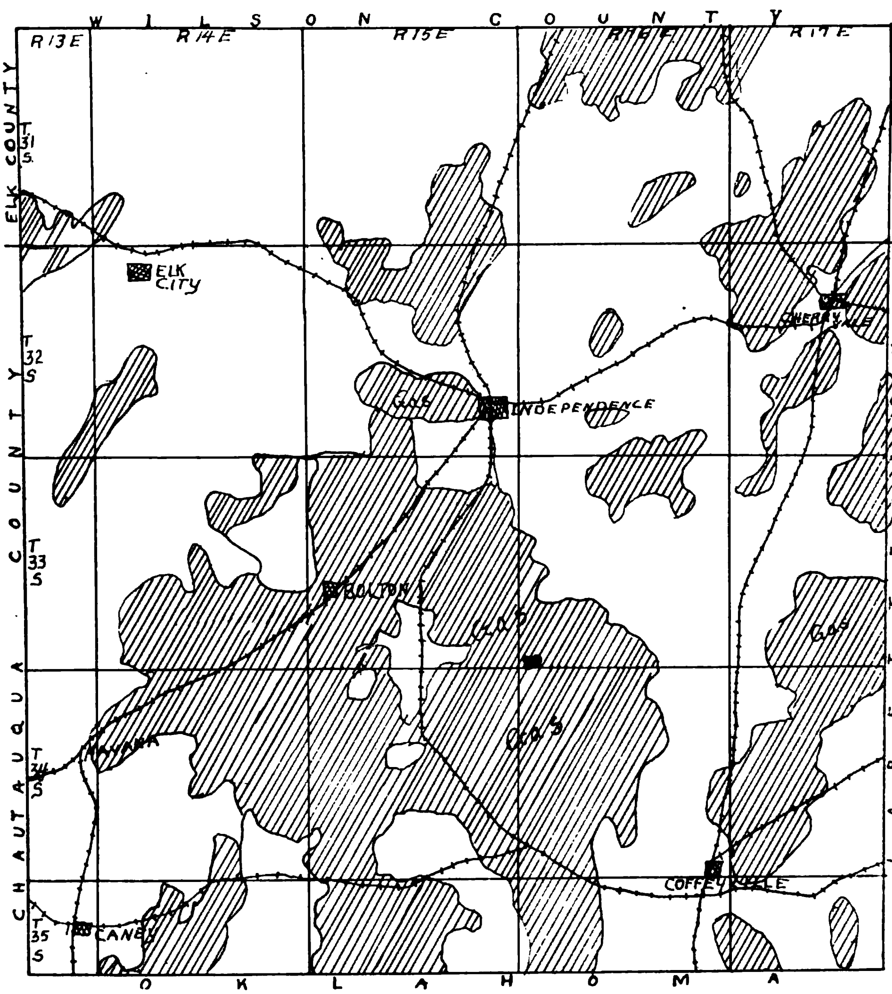

Fig. 66—Map showing producing areas in Montgomery county.

about 1905, and then declined rapidly on account of the discovery of larger producing fields in Oklahoma and the prevailing low prices for oil. Beginning in 1912 there was a renewed activity which has continued to the present except for a slump in 1915 which accompanied the break in prices produced by the flood of high-grade oil from the Cushing field.

The initial production from individual wells, of both oil and gas has been considerably larger in Montgomery county than in the counties farther north. Gas capacities of as high as 50,000,000 cubic feet and initial oil productions of more than 1,000 barrels per day are reported. The great majority of the wells, however, were much smaller than those mentioned.

The oil production declines rather rapidly to from 5 to 25 barrels per day but continues for several years.

The producing sands lie at depths of from 600 to over 1,000 feet below the surface. In the southwestern part of the county, the "Wayside" sand is found at about 600 feet; the "Wieser" sand, at about 700 feet, and the "Bartlesville" sand at about 1,100 feet. Gas production is had from a still deeper sand which is probably the upper part of the Boone chert (Mississippi lime.)

WELL RECORD FOR MONTGOMERY COUNTY, 1904-1916.

	Wells Completed				Initial Production	
Year	Oil	Gas	Dry	Total	Total	Avge.
1904	715	---	113	828	---	---
1905	104	89	40	233	---	---
1906	60	88	21	169	---	---
1907	21	31	4	56	---	---
1908	1	79	17	97	---	---
1909	5	100	22	127	---	---
1910	16	56	7	79	---	---
1911	60	36	22	118	1,300	21.7
1912	202	116	47	365	2,522	12.5
1913	602	173	92	867	5,871	9.8
1914	691	137	75	903	6,262	9.1
1915	201	129	49	379	2,505	12.5
1916	178	34	48	860	10,204	13.1

On January 1, 1917, Montgomery county was credited with 1846 producing oil wells.

Labette County.

Labette county lies immediately east of Montgomery county, and the producing area is an eastward extension of the Montgomery county pools.

The Cherokee shale outcrops in the southeastern part of Labette county so the producing sands lie at very shallow depths. Only a small portion of the county, an area of about one and one-half townships near Mound Valley in the west-central part of the county, is productive.

Both gas and oil are produced, but both are in small amounts. The gas production is more important than the oil. The depth to producing sands is from 600 to 700 feet.

There is very little chance for important production in the eastern half of the county where the Cherokee shale lies at the surface or at very slight depths.

WELL RECORD FOR LABETTE COUNTY, 1904-1916.

	Wells Completed				Initial Production	
Year	Oil	Gas	Dry	Total	Total	Avge.
1904	31	--	1	82	---	---
1905	-	--	1	1	---	---
1906	1	3	--	4	---	---
1909	-	8	3	11	---	---
1910	1	2	--	3	---	---
1911	-	1	--	1	---	---
1912	2	--	--	2	15	7.5
1913	-	3	--	3	---	---
1914	8	28	18	54	32	4.0
1915	19	7	3	29	105	5.5
1916	14	--	--	15	85	6.1

Bourbon and Crawford Counties:

Recent prospecting has opened a small field in the northwestern corner of Crawford county and the adjoining portion of Bourbon county at a depth of 600 feet. There are at present some 30 wells of 5-10 barrels capacity. The prospects promise considerable activity in this general region in the near future.

Chautauqua County.

Chautauqua county has been an important factor in oil and gas production in Kansas for a good many years. It lies immediately west of Montgomery county and has the same general conditions except that the surface rocks are higher in the Pennsylvanian system and, consequently, the productive sands are deeper than in Montgomery county. The surface rocks belong to the Lansing, Douglas, Shawnee and, in the extreme northwestern corner, to the Wabaunsee formation.

Oil and gas were first discovered in Chautauqua county about 1900 with the opening of the Peru pool, and since that time the history of the development has shown an almost perfect parallel to that of Montgomery county and the eastern district in general, with a great activity until 1904 or 1905, then a period of quiescence until about 1912, then a renewed activity for the past 5 or 6 years with a slump in 1915.

The productive area is practically confined to the southeastern half of the county, and nearly all the oil production is in the south-central part around Peru, Chautauqua and Sedan. These areas are shown in fig. 67.

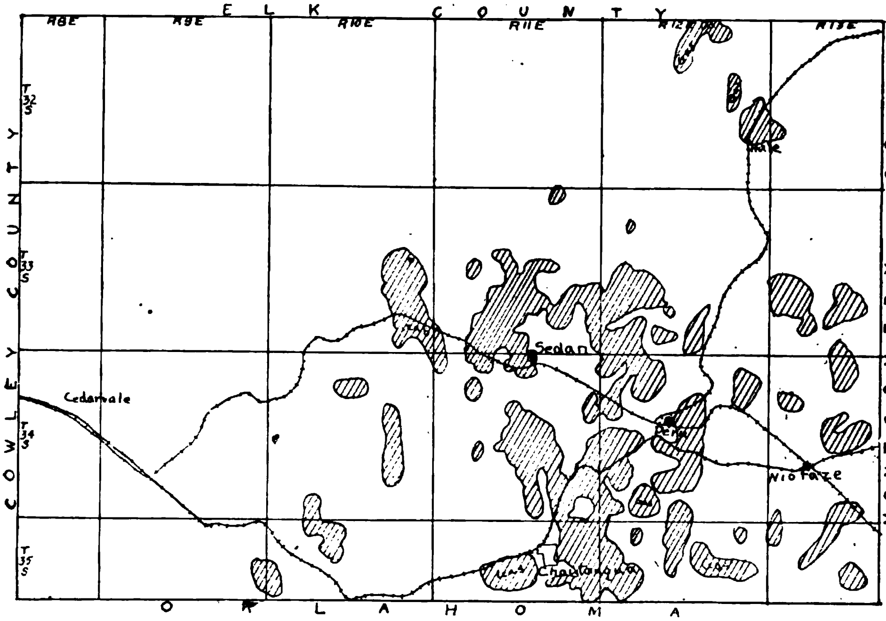

Fig. 67.—Map showing producing areas in Chautauqua county.

The wells are of fairly good size when brought in and settle in a few months to a reliable production of from 2 to 5 barrels per day. The sands are more or less lenticular and also vary in porosity so that dry holes are occasionally drilled in the midst of production.

The production of both oil and gas comes principally from three horizons.

1. The Red or Stray sand is encountered at a depth of between 1,100 and 1,200 feet in the Sedan pool. It is a fairly persistent sand in this area with a thickness of from 15 to 50 feet.

2. The Peru sand lies from 125 to 200 feet below the Red or Stray sand. It is found over practically the whole area and varies in thickness from 20 to 55 feet.

3. The Bartlesville sand occurs only in the southeastern part of the producing area. It lies about 300 feet below the Peru. The thickness of the Bartlesville varies but as a rule it is thicker than either the Red or Peru sands.

The Hancock sand is a non-persistent body of sand locally found between the Bartlesville and Peru, about 90 feet below the latter. Some gas is produced from the upper part of the Boone chert (Mississippi lime.)

WELL RECORD FOR CHAUTAUQUA COUNTY, 1904-1916.

	Wells Completed				Initial Production	
Year	Oil	Gas	Dry	Total	Total	Avge.
1904	566	--	64	630	---	---
1905	191	15	29	235	---	---
1906	125	6	25	156	---	---
1907	20	17	10	47	---	---
1908	16	5	3	24	---	---
1909	23	5	3	31	---	---
1910	42	4	14	60	---	---
1911	64	6	12	82	---	---
1912	182	12	28	222	1,355	21.2
1913	311	54	77	442	2,963	16.3
1914	308	30	38	376	7,398	23.7
1915	112	26	26	164	5,379	17.5
1916	440	20	51	511	2,515	22.5

On January 1, 1917, Chautauqua county was credited with 1,315 producing oil wells.

WESTERN DISTRICT.

The Western district includes the oil and gas fields of Butler county, and the gas fields of Cowley county. The comparatively barren belt between the eastern and western districts includes Elk and Greenwood counties, which for convenience are discussed in this connection.

Elk County.

The only important oil development in Elk county is near Longton in the southeastern part of the county. There is also a small field a short distance to the southeast, and near the junction of Elk, Chautauqua, and Montgomery counties several gas wells of exceptionally large capacity for the region were developed late in 1918 and early in 1919. This field is about 4 miles west of Elk City in Montgomery county and is known as the Elk City gas field.

All this development is adjacent to the producing areas of Chautauqua and Montgomery counties and the conditions are similar to those described for those counties.

The remainder of Elk county has had several test wells but the results have been practically negligible.

Greenwood County.

There has been some production of both oil and gas on a well-developed anticline near Beaumont. The wells so far are of only moderate size but give promise of a pool of considerable importance. Small oil wells have been found near Reese in the west-central part of the county and also near Vergil, northeast of Eureka. These areas have been fairly well tested and do not seem promising for large developments. In July, 1919, a well good for about 200 barrels per day was drilled in the northwestern part of the county in T. 23 N., R. 10 E.

Cowley County.

Several favorable structures are known in Cowley county but so far the production has not been of much magnitude.

Some oil and gas have been produced near Dexter in the southeastern part of the county. Most of the gas is composed so largely of nitrogen that it is not combustible.

Gas wells of good capacity and some small oil wells have been brought in east and southeast of Winfield. The principal sands lie in the alluvium filled valley of Walnut river.

A gas producing area of considerable importance lies between 1 and 3 miles north of Arkansas City. The wells are reported to have capacities of from 15,000,000 to 70,000,000 cubic feet of gas per day. The principal sand lies at a depth of about 3,200 feet but some gas is found in shallower sands. The productive area includes about 4 square miles.

There is one producing oil well near New Salem. Four or five dry holes have been drilled near this well.

Butler County.

The Butler county fields are by far the most important so far developed in Kansas. The principal fields are the Augusta, North Augusta and Eldorado. The minor pools are the Douglas, Smock, Sluss, Potwin and Elbing. The producing areas are shown in fig. 68.

Augusta field—The surface rocks of the Augusta, as well as of the Eldorado field, belong to the lower part of the Permian. The Florence flint, Fort Riley limestone and Winfield limestone are the main outcropping beds. These beds form prominent escarpments and make the determination of the surficial structure easy except in the alluvium filled valey of Walnut river.

The Augusta field was first developed as a gas field. A local company was organized in 1903 and a small gas well was brought in in 1905. The first well of any importance was completed on the Skaer farm southeast of the city in 1906. There was very little activity until 1912, when the Wichita Natural Gas company secured a large block of acreage on the structure which had been worked out to the south of the producing gas wells. The field was soon dotted with gas wells. In January, 1914, a location was made on the Frank Varner farm in sec. 21, T. 28 S., R. 4 E., but as it made only a small gas production, it was drilled deeper and oil was encountered at a depth of 2,466 feet. The well was carried to a total depth of 2,520 feet and the tubing was placed and production started July 18, 1914. Since that time development has been continuous, proceeding more slowly than is usual on account of the one company having practically all the acreage.

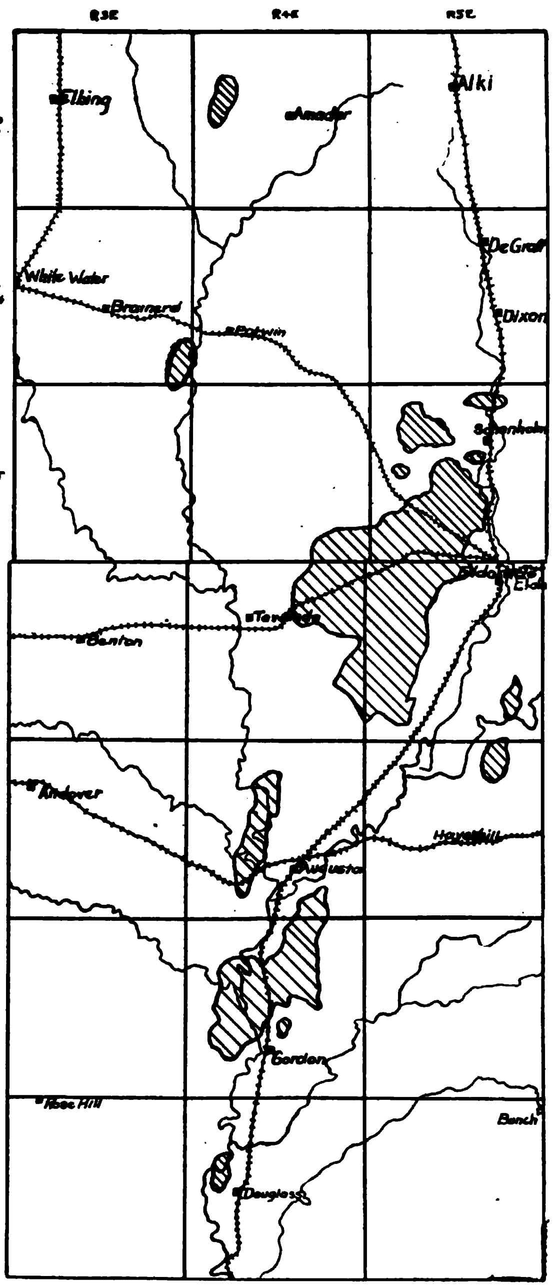

Fig. 68.—Map showing producing areas in Butler county.

The surface structure of the Augusta field shows a well-defined anticline with the production following the general outline of the structure. The sub-surface structure coincides in a general way with that of the surface but shows considerable minor folding that is not revealed at the surface. A fault in the oil sands, with a displacement of 100 to 150 feet is a prominent sub-surface feature not shown at the surface, but its course lies in the Walnut river valley and the scarp along the west side of the valley may represent the fault, but the east side cannot be determined. There are also smaller faults shown in the structural maps on the oil sands.

The gas producing area is in the northern part of the field, and includes all or part of secs. 35 and 26 in T. 27 S., R. 4 E., as well as a good part of the oil producing area covers all or

parts of sec, 35 T. 27 S., R. 4 E., and secs. 2, 3, 8, 9, 10, 11, 14, 15, 16, 17, 20, 21 and 29 in T. 28 S., R. 4 E.

The producing sands are five in number, viz:

(1) A gas sand at about 450 feet. This is not commercially productive since the gas contains so much nitrogen as to be worthless.

(2) A gas "sand" at 1,400 to 1,500 feet or deeper. The gas seems to be irregularly distributed through a series of mixed sediments, largely limestone. The wells have initial capacities of from 1,000,000 to 3,000,000 cubic feet per day and hold up well.

(3) An oil sand at 1,700 feet, which is productive only in secs. 21 and 24, T. 28 S., R. 4 E. The wells are small.

(4) An oil "sand" at 2,000 feet. This "sand" is the upper part of a limestone formation about 200 feet thick. The production occurs in scattered areas in secs. 2, 6, 9, 10, 11 and 14 in T. 28 S., R. 4 E., and in sec. 35 of the township to the north. The largest wells from this sand had initial productions of about 1,200 barrels per day but most of them are from 50 to 100 barrel wells. The oil ranges from 38 degrees to 42 degrees Be' in gravity.

(5) An oil sand at about 2,600 feet known as the Varner sand, which is practically co-extensive with the field. The productive horizon is the top part of a body of sand which is 300 feet thick without important shale breaks. The production is usually found in two streaks or pays which are separated by water sand, and water also occurs closely under the deep pay. The distance of the water surface below the top of the sand varies from 5 or 6 to 40 to 50 feet in different parts of the pool. The maximum well brought in from this sand had an initial production of 9,000 barrels per day. The oil averages about 33 degrees Be' gravity.

North Augusta field—The North Augusta field is a narrow belt, not over one-half mile in width and with a length of about 4 miles. It extends in a nearly north-south direction through secs. 28, 21, 16, 15, 9 and 10, T. 27 S., R. 4 E. The general conditions of structure and stratigraphy are similar to those of the Augusta field. The sands are somewhat shallower, the production comes from two or three pays in the 2,000 foot sand, which are small and scattered, and from the Varner sand. This sand has given large wells over the whole area but particularly at the southern end where the largest well in either of the Augusta fields was brought in with an initial capacity of 12,000 barrels.

Eldorado field—The general geologic conditions in the Eldorado field are entirely similar to those at Augusta. The structure is a large, irregular, dome-shaped anticline with an area practically coinciding with that of the producing field. As at Augusta,

the structure on the producing sands shows many minor irregularities that are not shown at the surface. The productive area lies in Twps. 25 and 26 S., R's. 4 and 5 E.

All or parts of the following sections are productive.

In T. 25 S., R. 4 E., secs. 25, 35 and 36.

In T. 25 S., R. 5 E., secs. 16, 20 21, 22, 27, 28, 29, 30, 31, 32, 33 and 34.

In T. 26 S., R. 4 E., secs. 1, 2, 3, 10, 11, 12, 13, 14, 15, 24 and 25.

In T. 26 S., R. 5 E., secs. 3, 4, 5, 6, 7, 8, 9, 17, 18, 19, 20, 29, 30, 31 and 32.

The Eldorado field was discovered in 1915. Several wells had been drilled in the vicinity of Eldorado and one well in the heart of the present field (in sec. 1, T. 26 S., R. 4 E.) was drilled by the city of Eldorado without encountering oil or gas in quantity. In the fall of 1915, the Stapleton No. 1 well in the NE1-4, SE1-4 sec. 5, T. 25 S., R. 5 E., found shallow production in a sand at about 600 feet but this was cased off and the well carried deeper. At 2,465 feet an oil sand was encountered and was penetrated to a depth of 2,511 feet. The well was finished Feb. 15, 1916.

The resulting development has proceeded somewhat more rapidly than in the case of the Augusta field since, although most of the area was controlled by one company, scattered tracts have caused much offset drilling. The early development was on the eastern side of the area, but worked westward and in the summer of 1917, Towanda pool was opened. This pool has had the largest wells so far drilled in Kansas or Oklahoma, the maximum initial production being about 20,000 barrels per day.

The sands of the field correspond in a general way to those of the Augusta field and are as follows:

(1) An oil sand at about 600 feet This sand was developed in the early history of the field and gave many wells of 25 to 30 barrels initial production. It is productive in all or part of secs. 16, 21, 22, 29, 28, 27, 31, 32, 33 and 34 in T. 25 S., R. 5 E., and parts of secs. 5 and 6, T. 26 S., R. 5 E.

(2) A gas sand at about 1,300 feet. This sand gives small gas wells at scattered localities in the field. The wells are small, and the supply of gas is not sufficient to supply the demand for fuel for development purposes.

(3) An oil sand at about 1,600 feet. This sand horizon is not continuous and is productive only in patches, principally in secs. 1, 2, 11 and 12, in T. 26 S., R. 4 E., and in secs. 8 and 17, T. 26 S., R. 5 E.

(4) An oil "sand" at about 2,000 feet which is productive at various points in the field principally in sec. 33, T. 25 S., R. 5 E., and secs. 8 and 17, T. 26 S., R. 5 E. This "sand" is in the upper part of a

limestone 2.000 foot sand in the Augusta field. The sand gives wells of only moderate production in the Eldorado field.

(5) An oil sand at 2,350 to 2,500 feet, which is the Varner sand of the Augusta fields. This sand is the principal producing horizon and is co-extensive with the field. The relations and nature of the sand are the same as in the Augusta field. The sand gives good wells in all parts of the field, but is especially productive in the Towanda pool in the western part of the field, where wells of as high as 20,000 barrels initial production were developed.

Minor Pools—Minor pools in the Butler county fields are the Smock pool in sec. 2, T. 27 S., R. 5 E., and sec. 35, in T. 26 S., R. 5 E.; the Sluss pool in secs. 25 and 26, T. 26 S., R. 5 E.; the Potwin pool, lying principally in sec. 36, T. 24 S., R. 3 E.; the Wilson pool, principally in secs. 8 and 9, T. 25 S., R. 5 E.; the Ramsey pool in secs. 2 and 3 of the same township, and the Elbing pool, lying principally in sec. 17, T. 23 S., R. 4 E., and the Douglas pool, northwest of Douglas, in T. 29 S., R. 4 E. None of these pools exceed 2 square miles in area. The geologic conditions are similar to those at Augusta pool. The production is from a horizon equivalent to or near the Varner sand. The Wilson pool also has production from the 600 foot sand. The wells have been of moderate size. Recently oil has been found northeast of the Elbing pool, east of Peabody in Marion county. The significance of this discovery can not be stated as yet, but some very good wells are being brought in.

The following table gives the well record, total and average initial production and the marketed production of the Butler county fields from 1914 to 1918 inclusive.

	Wells Completed				Initial Production		Marketed
Year	Total	Oil	Dry	Gas	Total	Average	Production
1914	29	5	--	24	47	9.4	
1915	60	22	4	34	3,320	15.1	
1916	977	836	126	35	213,633	255.8	
*1917	1,184	1,015	148	21	294,830	294.0	31,269,169
*1918	1,440	---	259	42	306,713	269.3	36,069,670

*Oil and Gas Journal.

OIL AND GAS FIELDS OF OKLAHOMA.

The oil and gas fields of Oklahoma may be divided into the main field in the northeastern part of the state and the outlying areas in the other sections. The main oil and gas field may be subdivided into several districts as follows: Nowata district or shallow field, Bartlesville district, Sapulpa district, Tulsa district, Muskogee district, Okmulgee district, Osage district, Pawnee county or Cleveland district, Cushing district and Kay county district. Most of these districts are again subdivided into pools or fields. The location of the principal pools is shown on the state map (Pl. I.) In the following sections each district is considered in turn and the pools contained in each are noted separately.

NOWATA DISTRICT.

The Nowata district includes Nowata county and the northern part of Rogers county. It is the portion of the Cherokee field known as the "Shallow field" with the addition of the Adair pool west of Nowata. The district may be divided into the following pools: Coody's Bluff-Alluwe, Delaware-Childers, Nowata or Claggett, California Creek, and Adair. The producing areas are shown in fig. 69.

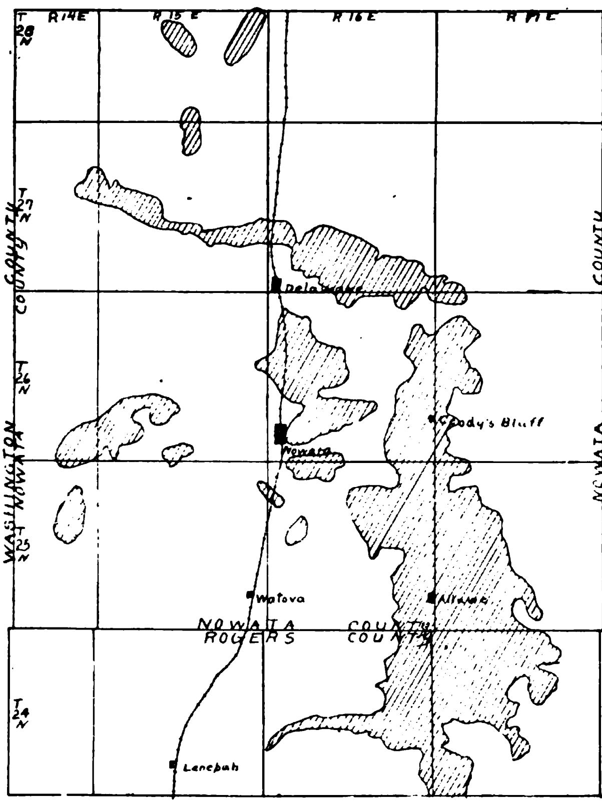

Fig. 69.—Map showing producing areas in the Nowata district.

Coody's Bluff-Alluwe pool — The Coody's Bluff-Alluwe pool lies principally on the east side of the Verdigris river, extending from Spencer Creek west of Chelsea on the south, northward to the line between Tps. 26 and 27 north. The total length of the pool from north to south is about 18 miles. The greatest width is about the latitude of Alluwe Post Office, where it is about 5 miles, and the least width is about 2 miles in the vicinity of Coody's Bluff Post Office. The total area of the pool is about 75 square miles. The northern and southern portions of the pool are sometimes considered separately as the Coody's Bluff and Alluwe pools, the division line being drawn at Salt Creek, where there is a rather marked break in the development. The extreme southern part of the pool lies west of Chelsea and is sometimes known as the Chelsea pool. The northern line of the Coody's Bluff-Alluwe pool is merely one of convenience, as the development is practically continuous with that of the Delaware-Childers pool.

The development is fairly solid over the area as outlined, although there are occasional dry holes scattered through the field sometimes in close proximity to producing wells. There are also occasional gas wells throughout the field, but they are much more abundant along the east side, especially in the Coody's Bluff portion of the field where the gas development extends as much as 2 miles to the east of that of the oil.

The wells in the pool vary considerably in depth on account of the irregularities of the surface and on account of the fact that the axis of the pool is diagonal to the strike of the rocks, i. e., the wells in the northern part of the pool are started at a higher geological horizon than those at the southern end of the field and the depth to the producing sands is correspondingly greater. The depth of the wells in the Alluwe portion of the pool varies from about 350 to about 575 feet in the Coody's Bluff portion from about 500 to about 750 feet. In general the shallower wells are to the south and east and the deeper ones to the north and west. The wells in the southern part of the pool are started near the upper surface of the Fort Scott (Oswego) formation and those in the northern part of the field, with few exceptions, start below the base of the Altamont.

Two producing sands are known in each portion of the pool. The upper is probably the Bartlesville sand and is found about 400 feet below the top of the Fort Scott or Oswego limestone. It furnishes by far the greater portion of the production. The lower sand in the southern portion of the pool is about 65 feet lower than the Bartlesville. The lower sand in the northern part is 200 feet below the Bartlesville. It is known as the Burgess sand. The Bartlesville sand varies from 20 to about 25 feet and the lower sand in the Alluwe portion of the field from 15 to 20 feet in thickness.

The oil from this field is usually a dark green or greenish black in color and its specific gravity is in the neighborhood of 35 degrees Baume. The base is of mixed paraffin and asphalt. The proportions of the two vary greatly but the paraffin usually predominates.

The following table gives the well record and the total and average initial production for this pool in 1905, 1906 and 1909, 1910 and 1911. For 1907 and 1908 the statistics for the whole shallow-sand district are combined and those for the separate pools cannot be given. The southern part of the field is divided by the U. S. Geological Survey into the Chelsea and Alluwe pools.

TABLE SHOWING AVERAGE INITIAL CAPACITIES OF WELLS IN THE COODY'S BLUFF-ALLUWE-CHELSEA POOL.

	—Coody's Bluff—		—— Alluwe ——		——Chelsea——	
Year	Total	Average	Total	Average	Total	Average
1905	7,160	27.3	5,116	31.9	3,960	18.1
1906	22,845	44.8	13,749	33.6	6,828	19.6
1909	1,565	22.7	7,196	32.4	7,405	33.1
1910	1,625	24.3	4,465	25.5	7,920	24.6
1911	928	17.2	1,674	18.0	1,935	15.6

WELL RECORD OF THE COODY'S BLUFF-ALLUWE-CHELSEA POOL.

	Coody's Bluff				Alluwe				Chelsea			
Year	Total	Oil	Dry	Gas	Total	Oil	Dry	Gas	Total	Oil	Dry	Gas
1905	280	262	8	10	165	160	4	1	244	218	20	6
1906	549	510	28	11	441	409	25	7	400	348	44	8
1909	72	69	3	--	246	222	24	-	262	224	38	-
1910	73	67	6	--	190	172	7	1	351	322	25	4
1911	56	54	2	--	98	93	4	1	138	124	11	3

Since 1911 the published statistics have grouped all the shallow sand pools. It is seen in the tables given above that the Coody's Bluff-Alluwe-Chelsea pool reached its maximum between 1906 and 1909. Development has continued to the present, but only in a small way. The statistics for the entire shallow sand area are given at the end of the discussion of the Nowata district.

Nowata pool—The Nowata or Claggett pool is the western extension of the Coody's Bluff pool. It embraces about 5 square miles in Nowata county, in secs. 8, 9, 16, 17, 18, T. 26 N., R. 16 W. The depth of the wells varies from about 550 feet near Verdigris river on the eastern side of the field to about 725 to 750 feet on the western edge of the pool. The productive sand is the Bartlesville, which lies from 390 to 410 feet below the top of the Fort Scott or Oswego lime. The sand varies in thickness from 15 to 20 feet and is separated by 5 to 10 feet of sandy shale from a lower sand of about the same thickness. The wells in the eastern part of the pool are started about the top of the Big Lime (Altamont) and those in the western part about the horizon of the Lenapah limestone.

The Nowata pool is pretty well surrounded by dry holes which define the area of the pool. There are also dry holes scattered through the pool, but it is probable that many of these are not truly dry, but gave a smaller production when they were brought in than was expected, or than could be profitably handled at that time. The number of gas wells in the pool is small. Several occur in secs. 16 and 21 about 2⅛ miles northwest of Nowata and another group is about 5 miles southwest of the town. The town is supplied from this group of wells. Four or five more wells are scattered through the field. The supply is sufficient for local demands only.

The following table gives the well record of the pool and the total and average initial production of the wells of the pool from 1909 to 1911.

WELL RECORD OF NOWATA OR CLAGGETT POOL.

	Wells Completed				Initial Production	
Year	Oil	Gas	Dry	Total	Total	Avge.
1909	213	4	15	232	5,620	26.4
1910	103	2	4	109	2,150	20.9
1911	88	36	25	149	1,202	13.7

Delaware-Childers pool—This pool extends westward from the Childers Post Office to the northeastern corner of T. 27 N., R. 14 E.

It is the westward extension of the northern end of Coody's Bluff pool and the general conditions are approximately the same. Along Verdigris river the width of the pool is a little over 2 miles, but north and west of Delaware it is less than one-half mile. The logs of the dry wells show that the sand is present on both sides of the productive area, but it seems to be tight. The sand is apparently continuous with that of the Coody's Bluff-Alluwe field and is therefore thought to be the Bartlesville sand. The depth of the oil varies from 670 to about 900 feet. The initial production of the wells in this pool was high, many of the wells starting off at better than 150 barrels. The pool was developed very rapidly and the decline in production was also rapid; most or all of the wells now producing are being pumped and some have been abandoned. The production now is small compared to the initial production. The oil is very similar in character to that of the Coody's Bluff pool.

The well record of this pool and the initial production of the wells are shown in the following table:

	Wells Completed				Initial Production	
Year	Oil	Gas	Dry	Total	Total	Avge.
1909	475	6	65	546	57,320	120.7
1910	673	4	80	757	59,185	88.0
1911	597	10	43	650	54,266	90.9

California Creek pool—The California Creek field is located principally along the creek of that name in Tps. 28 and 29 N., R. 15 E., about 6 miles south of Coffeyville, Kan. The pool was developed principally in 1911 and 1912. The majority of the wells are gassers and the pool is much more important on account of its gas than on account of its oil production. In December, 1912, a total of 25 gas wells had been brought in which had an average capacity estimated at from about 3,500,000 to about 4,250,000 cubic feet per day, and an average initial pressure of 373 pounds to the square inch. A large part of the supply goes to Coffeyville, Kans., and some to other towns in Kansas through the lines of the Kansas Natural Gas Company. The general geologic conditions of this pool are the same as those of the Delaware-Childers pool.

Adair pool—The Adair pool is located about 6 miles west of Nowata, principally in T. 26 N., R. 15 E. While it lies in the Nowata district as defined in this book, it is more closely related geologically to the Hogshooter and other pools of the Bartlesville district than to the shallow pools east and north of Nowata. The wells start about the top of the Coffeyville formation and encounter the Fort Scott (Oswego) lime at about 625 feet and the top of the Bartlesville sand about 400 feet lower. The thickness of the Bartlesville sand is reported as being 34 feet. The Adair pool was discovered in October, 1911, and its development was very rapid.

* * * * * * * * * *

As remarked before, the statistics for all the shallow sand pools

have been combined since 1911. The combined statistics are given below.

WELL RECORD OF THE CHEROKEE SHALLOW SAND (NOWATA) DISTRICT.

Year	Wells Completed				Initial Production	
	Oil	Gas	Dry	Total	Total	Avge.
1912	1,242	121	139	1,231	17,672	16.5
1913	1,071	62	113	1,417	23,236	18.7
1914	1,472	9	77	1,558	16,172	11.0
1915	519	27	54	600	10,595	20.4
1916	1,105	19	95	1,219	15,972	14.5
*1917	674	6	77	757	11,809	17.5
*1918	730	8	89	827	9,903	13.5

*Oil and Gas Journal.

The great drop in the number of wells drilled in 1915 was due to the low price of oil which prevented the profitable working of very small wells. The rise in the average initial production shows that only such wells were drilled as had some chance of being fairly good producers. The decline in operations in this district is shown by comparing the number of wells drilled in the entire district in 1915 (600) with the number drilled in the Coody's Bluff-Alluwe-Chelsea pool alone in 1906 (1,390) or in the Delaware-Childers and Nowata pools in 1910 (866.) The total initial production of the district in 1915 was less than one-fourth that of the Coody's Bluff-Alluwe-Chelsea pool in 1906.

Operations increased somewhat in 1916 due to higher prices for oil but there can be no doubt that the district is long past its prime. The territory has been so thoroughly tested that the discovery of any important pools is practically impossible. However, the production will continue for several years if oil remains at its present high price.

BARTLESVILLE DISTRICT.

The Bartlesville district lies to the west of the Nowata district and includes all of Washington county and a narrow strip along the east side of Osage county. For consideration here the district is divided into the following pools: Canary, Copan, Wann, Dewey-Bartlesville, Squirrel, Hogshooter and Vera. In general, the oil and gas are found in the same sands as in the Nowata district, but on account of the prevailing westerly dip, they occur at considerably greater depths, usually over (1,000) feet. On this account the district has usually been known as the Cherokee deep-sand field in distinction from the shallow-sand field to the east. The developed areas in the northern part of the district are shown in fig. 70 and in the southern part in fig. 71.

Canary pool—The Canary pool lies in the extreme northeastern part of Washington county in T. 29 N. R's. 13 and 14 E. The pool embraces an area of about 10 square miles and has its long axis in a northeast-southwest direction.

The productive oil horizon in the Canary pool is reached at depths of from 1,175 to 1,200 feet, with the greatest depth in the southwestern part of the field. The wells start in the shales of the Wilson formation of Kansas. The productive oil sand is the Bartlesville, which also furnishes some gas. Gas is also found in the Mississippi gas sand. The Bartlesville is unusually thick in this pool. The majority of the logs show thicknesses of from 40 to 60 feet and some of them as much as 110 feet. It is probable that when only 40 feet or less is shown in the log that the sand was not drilled through. A large number of wells produce both oil and gas, in which case the gas comes from the upper portion of the sand and the oil from the lower portion. There are also several gas wells scattered through the northeastern part of the pool, while the southwestern part is almost strictly a gas field. The whole pool is remarkably free from dry holes.

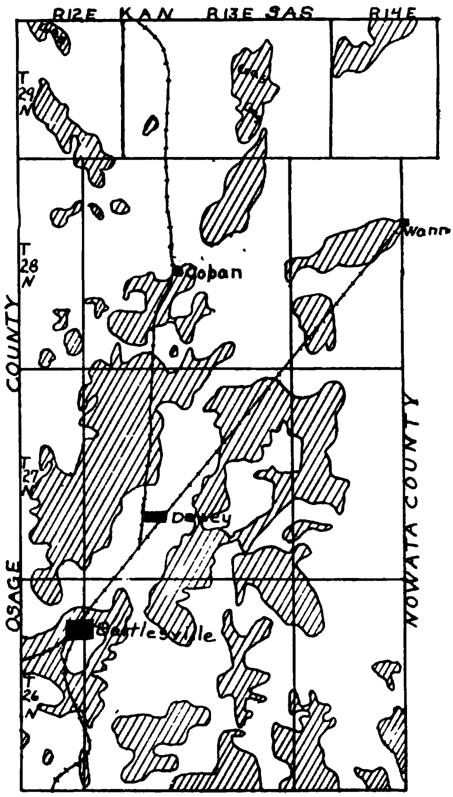

Fig. 70.—Map showing producing areas in the northern part of the Bartlesville district.

The Canary is probably considered as a part of the Copan pool in the published statistics of the United States Geological Survey. For the Copan pool the average initial production is given at 54.4 barrels in 1909 and 33.7 barrels in 1910. These figures are probably fairly accurate for the Canary pool.

The gas field of this pool is continuous with the pool of Caney, Kans. The gas is obtained in part from the Bartlesville sand and in part from the Mississippi gas sand. The average initial capacity of the wells was determined as 31,570,000 cubic feet per day and the average pressure was 440 pounds per square inch. The demands made on the field were very heavy and the wells deteriorated rapidly. In September, 1911, the capacity was determined as 916,000 cubic feet and the pressure as 18 pounds. Measures are being taken to revivify the wells by pumping off the water and also by drilling

deeper into the sand in the wells in which it was not drilled through when they were brought in.

The well record and statistics of initial production of the oil wells for this pool are included in the Copan pool.

Copan pool—The Copan pool extends from northeast to southwest across T. 28 N., R. 13 E. It occupies an area of about 8 square miles and is practically continuous with the Canary pool on the north and with the Bartlesville-Dewey pool on the south. Some development in the southeast part of T. 28 N., R. 12 E., extends the development into Osage county and may be considered a part of the Copan pool. The pool is primarily an oil producer, although there are a few scattered gas wells.

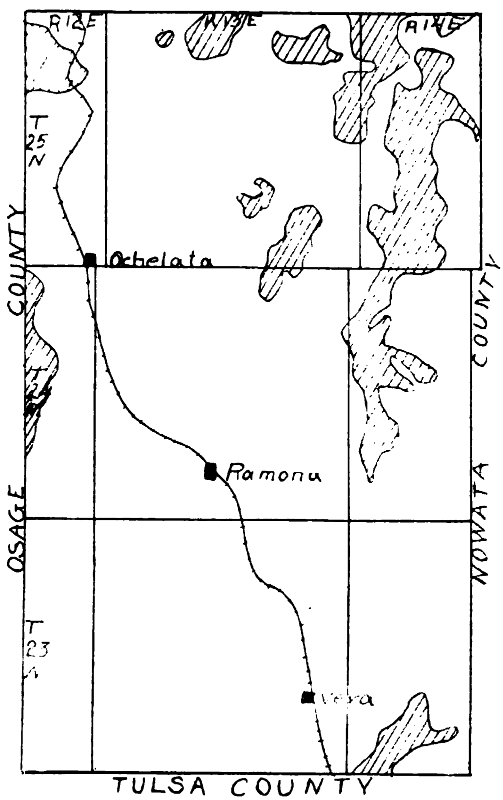

Fig. 71.—Map showing producing areas in the southern part of the Bartlesville district.

The sands found are the same as in the Canary pool, the Bartlesville and the Mississippi gas sand, and in addition a shallow sand which was overlooked in the early development. The Bartlesville is found at from 1,300 to 1,450 feet below the surface and about 350 feet below the top of the Fort Scott (Oswego) lime. It is about 29 feet thick. The Mississippi sand lies about 200 feet below the Bartlesville and is about 25 feet thick. The shallow sand lies about 700 or 800 feet below the surface and is probably the sandstone in the upper part of the Labette shale.

The average initial production of the oil wells drilled in the Copan (probably including the Canary and Wann pools) in 1909 was 54.4 barrels and in 1910 was 33.7 barrels.

Wann Pool—This pool is located to the east of the Copan pool in the west part of T. 28 N., R. 14 E. The development consists of a group of wells from 1 to 2 miles west of Wann and another group about 4 miles southwest of Wann. The general conditions of the pool are similar to those of the Copan pool. The development is

shown together with that of the Copan and the northern part of the Bartlesville-Dewey pools in fig. 25.

The well record of the Copan (including Canary and Wann) pool is given in the following table:

WELL RECORD OF THE COPAN POOL.

Year	Wells Completed				Initial Production	
	Oil	Gas	Dry	Total	Total	Avge.
1909	43	35	17	95	2,340	54.4
1910	121	65	22	208	4,082	33.7
1911	216	21	45	282	5,890	27.3
1912	482	41	50	573	10,972	22.8
1913	393	26	50	469	6,309	1[illegible]1
1914	266	76	79	421	7,022	26.4

For 1915 all the Washington county pools were combined in the published reports.

Dewey-Bartlesville pool—The Dewey-Bartlesville pool occupies a large area extending from the north line of T. 27 N., on the north to the south line of T. 26 N., on the south and from the eastern line of Washington county west across the country and from 1 to 3 miles into Osage county. There are many undeveloped spots in this area, but except along the eastern line of Washington county there are very few sections that do not have some producing wells. The portion of the pool north from Bartlesville is divided into two fairly distinct divisions by a belt along the Missouri, Kansas & Texas Railway, which has several dry wells. To the north the pool is practically continuous with the Copan pool, to the southeast with the Hogshooter pool and to the southwest with the Ochelata-Avant development. The division into separate pools in thus largely one of convenience, but the lines of separation are drawn at more or less pronounced breaks in the development.

Four sands have proven productive of oil or gas or both in the Dewey-Bartlesville pool. The shallowest is found about 525 feet below the surface and about 125 feet above the top of the Big Lime. It is known as the McEwin sand and is about 30 feet thick, medium-grained and generally light in color. It is probably a lens in the Nowata shale. In some of the wells of the northern part of the pool a sand known as the Peru sand has proven productive of oil. This sand is about 20 feet thick and lies just below the Big Lime. Neither of these shallow sands has proven of great importance and in the early development were usually ignored in the effort to reach the deeper and more productive sands. Some fairly good wells have been brought in from both sands, however, and it is probable that as the deep sands are exhausted these shallow sands will prove worthy of development in view of the high price paid for oil in comparison to the price in the early days of the pool.

The Bartlesville is by far the most important oil-producing sand of the pool. It lies between 1,200 and 1,350 feet below the sur-

face and its top is about 350 feet below that of the Fort Scott (Oswego) limestone. The sand varies in thickness from 25 to 40 feet with some logs showing up to 60 feet. In character the sand is coarse, and light to brownish in color. The gas is usually present in the upper part of the sand.

The Burgess sand is the most important gas sand of the pool. It lies a short distance above the Mississippi lime and about 150 feet below the Bartlesville sand. The sand seems to be persistent throughout most of the pool.

The Dewey-Bartlesville pool was one of the first developed in Oklahoma and has been a great producer ever since. It is now undoubtedly past its prime, but the intensive development of the pool and the working of the shallow sands will undoubtedly prolong the life of the pool for years to come.

The gas wells of this pool occur principally in the vicinity of Bartlesville and in a belt extending to the east and connecting with the Hogshooter pool. There are also several gassers in a belt extending north and south through Dewey. The initial capacity of several wells in this and the Hogshooter pool was determined as 15,850,000 cubic feet per day and the average pressure as 464 pounds. In September, 1911, the average pressure was 219 pounds and the average capacity was 9,283,000 cubic feet. The wells were drawn on for practically their full capacity and in view of this fact have held up remarkably well. Many of them, however, are now very small producers or have been abandoned.

The well record and the initial production of the wells in the years for which statistics are available are shown in the following tables, in which the Dewey and Bartlesville pools are considered separately.

WELL RECORD OF THE BARTLESVILLE POOL.

	Wells Completed				Initial Production	
Year	Oil	Gas	Dry	Total	Total	Avge.
1906	606	61	123	790	---	---
1909	238	5	11	254	11,475	42.2
1910	232	8	11	251	10,196	43.9
1911	165	8	15	188	4,955	30.2
1912	499	40	45	584	11,716	23.5
*1913	829	44	75	948	19,412	28.4
*1914	389	21	44	454	3,925	10.1

*Including Hogshooter.

WELL RECORD OF THE DEWEY POOL.

	Wells Completed				Initial Production	
Year	Oil	Gas	Dry	Total	Total	Avge.
1909	152	1	8	161	5,065	33.3
1910	188	1	3	192	6,073	32.3
1911	290	34	15	339	7,558	26.1
1912	481	29	26	536	12,306	25.6
1913	770	47	55	872	15,842	20.6
1914	440	13	33	486	5,093	11.6

For 1915 the statistics of the Dewey and Bartlesville pools are included with the others of Washington county.

Squirrel pool—The Squirrel pool or Squirrel sand development centers about six miles east and two miles north of Bartlesville. The area usually included under this name includes secs. 35 and 36 of T. 27 N., R. 13 E.; secs. 1, 2 and 12 of T. 26 N., R. 13 E., and secs. 6 and 7 of T. 26 N., R. 14 E. The pool takes its name from the Linnie Squirrel farm in the NW. 1/4 sec. 7, T. 26 N., R. 14 E.

The Squirrel sand lies below the Fort Scott limestone. It is about twenty feet thick and the lower portion usually contains water. Several wells in the Squirrel sand occur in other portions of Washington county, but not in sufficient number in one locality to constitute a Squirrel pool.

Hogshooter pool—The Hogshooter pool includes a strip on both sides of Hogshooter creek in the southeastern part of Washington county. The pool is about 12 miles long from north to south and from a fraction of a mile to about 4 miles in width. Only the northwestern part of the pool is oil producing, the larger portion of the pool constituting one of the greatest gas fields in the state. The pool is practically continuous with the Dewey-Bartlesville pool on the north and the general conditions are the same as for that pool and the Copan pool.

There are several productive sands. The highest is about 40 feet below the Big Lime and is about 40 feet thick. The Bixler sand is just below the Oswego lime and varies from 5 to 50 feet in thickness. Neither of these sands has proven of much importance, although some oil has been obtained from both. The Peru (?) sand is about 200 feet below the top of the Fort Scott (Oswego) lime. The thickness shown in the logs is usually 30 to 40 feet, although as little as 10 feet is shown in some logs. The Bartlesville said lies about 200 feet below the Peru sand or about 400 feet below the Oswego lime. As in the other pools of the district this is the most important sand. The thickness is usually shown as 30 feet, but there is much variation in the logs. The Mississippi sand is reached by only a few of the wells. It produces principally gas.

The condition of the gas field has already been considered in connection with the Bartlesville field. Several of the larger gas companies ran lines into the field and the wells failed rather rapidly under the demands made upon them. The gas was piped to Bartlesville, Dewey and Miami, Okla., for use in the smelters, cement plant and mining camp, and to the principal cities in southeastern Kansas and to Joplin, St. Joseph, and Kansas City, Mo. Although greatly depleted the field is still (1918) an important gas producer.

The well record and the initial production of the oil wells of the pool are shown in the following table:

WELL RECORD OF THE HOGSHOOTER POOL.

	Wells Completed				Production — Initial	
Year	Oil	Gas	Dry	Total	Total	Avge.
1909	71	24	12	107	3,759	[illegible]
1910	109	38	8	155	5,115	46.9
1911	192	116	31	339	8,795	45.8
1912	285	68	43	392	13,151	46.1

For 1913 and 1914, the statistics of the Hogshooter pool are combined in those of the Bartlesville pool.

Vera pool—The Vera oil and gas pool is the most recent development of note in the Bartlesville district, having had its principal development in 1915 and 1916. It is located in the extreme southeastern part of Washington county, with the principal productions in the sections around the corner of Tps. 22 and 23 N, Rs. 13 and 14 E. The production is both oil and gas. The oil wells had initial productions ranging from a few barrels to 350 barrels per day and the gas wells from 2,000,000 to 18,000,000 cubic feet. The daily production late in 1916 was estimated at 500 barrels. The geologic conditions and sands are quite similar to those of the Hogshooter pool.

As compared with the Nowata or Cherokee Shallow Sand district, the Bartlesville or Cherokee Deep Sand district was developed somewhat later. The territory is still showing occasional wells of 200 or 300 barrels initial capacity but the majority are small pumpers. The territory has been so well tested that there is little or no possibility of any large pools being opened. However, in the early drilling, a dry hole was thought to condemn a larger territory than has proven to be the case and some good producers have been drilled in territory originally thought to be dry.

For the purpose of showing the development of the whole district, the well record of the Cherokee Deep Sand district is given for the past several years. This district includes the pools described under the Tulsa and Bartlesville districts as considered in this book. For 1918 a small part of the production of the Sapulpa district is included.

WELL RECORD OF CHEROKEE DEEP SAND DISTRICT.

	Wells Completed				Initial Production	
Year	Oil	Gas	Dry	Total	Total	Avge.
1905	225	15	33	273	14,780	65.7
1906	606	61	123	790	44,367	73.2
1907	815	61	65	941	74,824	91.8
1908	605	32	53	690	36,561	60.4
1909	519	71	62	652	34,130	65.8
1910	627	114	61	802	28,903	46.1
1911	806	124	114	1,074	30,135	37.4
1912	2,444	206	256	2,906	76,025	31.1
1913	2,724	406	299	3,429	67,505	24.8
1014	1,331	222	236	1,789	19,986	15.0
1915	324	69	78	471	7,926	24.5
1916	1,087	54	153	1,294	18,794	17.3
1917	648	22	93	763	14,034	23.2
1918	890	115	325	1,330	22,638	25.4

TULSA DISTRICT.

The Tulsa district includes the portion of Tulsa county north and east of Arkansas river and a small area in western Rogers county southeast of Collinsville. By far the greater part of the development is included in a district about 5 miles wide extending from Skiatook on the north to Tulsa on the south, a distance of about 13 miles. This district is usually divided into separate pools, the Skiatook, Bird creek, Turley and Flat Rock, but, since the conditions are so similar in all of them, these pools are considered together as the Bird Creek-Flat Rock pool in this book. Besides the Bird Creek-Flat Rock pool the other important pool of the district is the Collinsville-Owasso gas pool which lies in Tulsa and Rogers counties, southwest of Collinsville and northeast of Owasso. There are also a considerable number of gas wells in a belt extending southwest from Dawson to the east of Tusla and in another belt extending west from Tulsa to Sand Springs. The producing areas are shown in fig. 72.

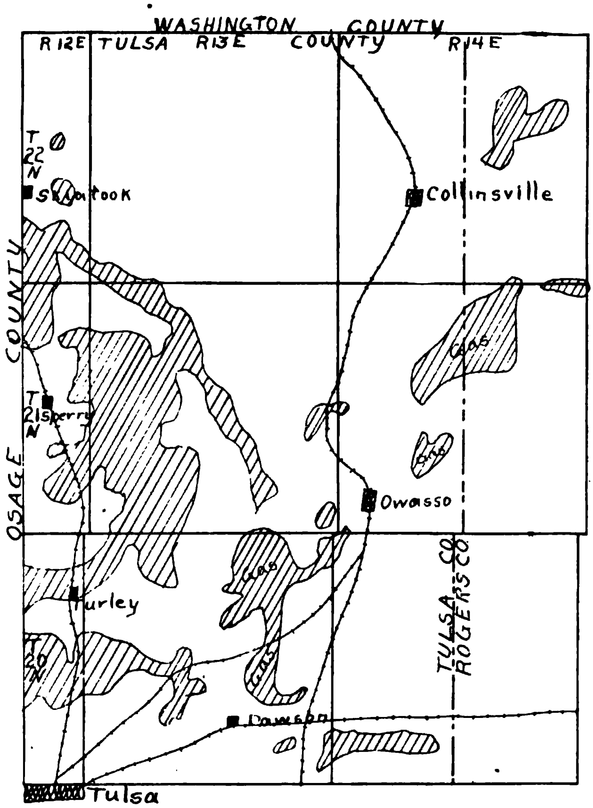

Fig. 72.—Map showing producing areas in the Tulsa district.

Bird Creek-Flat Rock pool—The Bird Creek-Flat Rock pool lies between Tulsa and Skiatook. Bird creek flows from north to south through the pool and gives it its name. The north end of the pool is often known as the Skiatook pool and the south part is known as the Flat Rock pool from the development along the creek of that name. The development in a northeast-southwest belt passing through the village of Turley is sometimes distinguished as the Turley pool. The geologic conditions are practically the same as for the pools of the Nowata and Bartlesville districts. The

wells are started very near the horizon of the limestone which has usually been called the Lenapah, but which has been found to be about 100 feet higher in the section than that limestone. The wells are thus started at the same horizon as those of the Red Fork and Glenn pools in the Sapulpa district to the south and a little lower than those of the Dewey-Bartlesville pools in the Bartlesville district to the north. The productive sands are encountered at a depth of about 1,000 to 1,200 feet. The productive sands are about the same as in the Dewey-Bartlesville pool. The Bartlesville sand is the principal producer and is found at a depth of very nearly 1,200 feet.

The Bird-Creek-Flat Rock pool was one of the earlier developments in the Cherokee Nation and has been productive of many large wells. The limits of the separate pools comprising the large pool have been well defined for some time and the development has been intensive rather than extensive.

The well record and initial production of the wells of this pool in the years for which statistics are available are as follows:

WELL RECORD OF THE BIRD CREEK-FLAT ROCK POOL.

	BIRD CREEK						FLAT ROCK					
		Wells Completed			In. Prod.			Wells Completed			In. Prod.	
Year	Total	Oil	Dry	Gas	Total	Av.	Total	Oil	Dry	Gas	Total	Av.
1909	101	78	17	6	3,595	46.1	95	89	5	1	12,970	145.7
1910	188	165	20	3	9,510	57.6	--	--	--	--	------	----
1911	265	233	23	9	10,495	45.0	--	--	--	--	------	----

Collinsville pool—The Collinsville pool lies to the east of Bird Creek pool, in the north-central part of T. 21 N., R. 14 E. There is some development of gas near Owasso in the southwestern part of the same township. The general conditions are the same as for the former pool except that the wells start in the section a short distance above the Big Lime or Oolagah formation. Some oil is found, but the pool is far more important as a gas than as an oil producer.

The gas wells are of large capacity, but usually not so large as those of the Hogshooter pool. A good share of the product is utilized by the large zinc smelters recently erected at Collinsville and by the brick plant there.

Since 1911, the published statistics of the United States Geological Survey combine the well records of the Bartlesville and Tulsa districts as the Cherokee Deep-sand district. This table has been given in connection with the Bartlesville district.

SAPULPA DISTRICT.

The Sapulpa district includes the Glenn pool and some smaller outlying pools near Jenks, Red Fork, Taneha, Kelleyville, Mounds, Leonard and Bixby. The conditions throughout the pool are very

similar and a discussion of the Glenn pool applies to the smaller pools so far as the number, thickness and character of sands is concerned. The producing areas, except the Leonard, Broken Arrow and Bristow pools are shown in fig. 73.

The Glenn pool—The Glenn pool is one of the greatest oil producing areas in the world. It was opened by a well drilled by Galbreath and Colcord in the summer of 1906. Development was very rapid and the pool soon became a phenomenal producer. The older wells of the pool have decreased greatly in production, but the pool

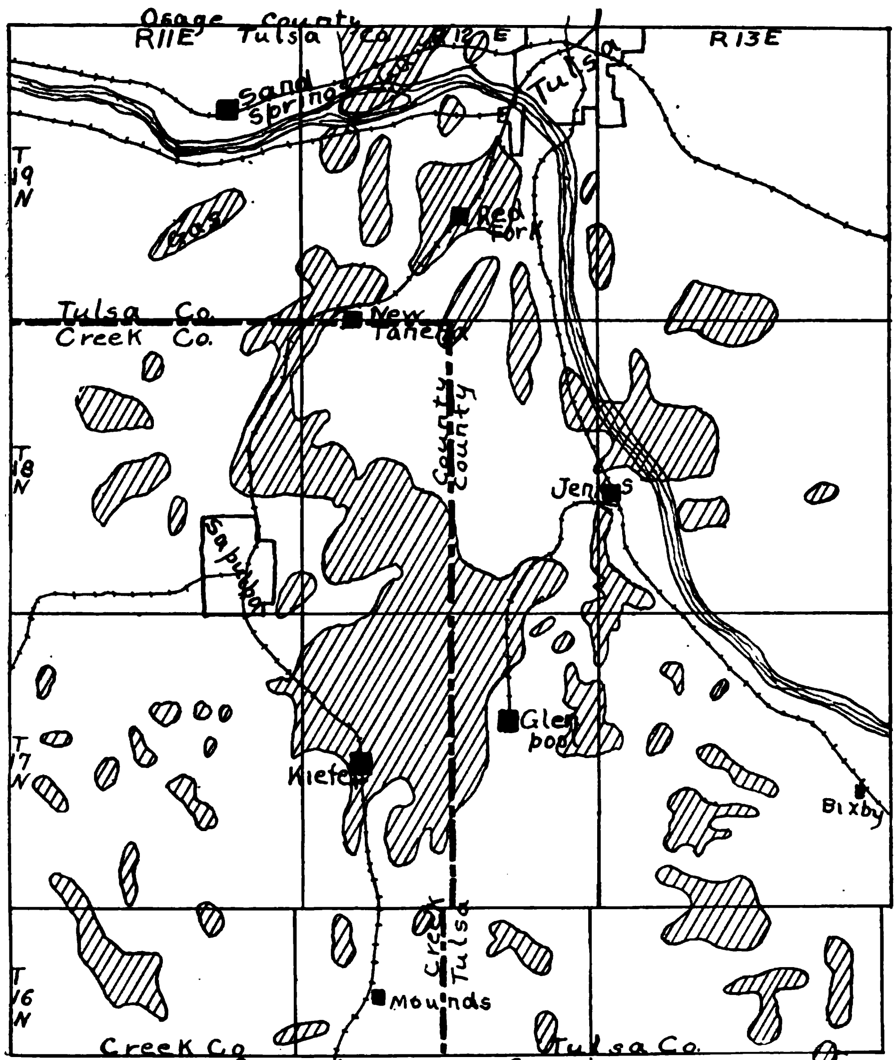

Fig. 73.—Map showing producing areas in the Sapulpa district.

has been extended and the total production is still very great, although it has receded considerably from its maximum and the pool is undoubtedly past its prime.

The pool lies to the east of Sapulpa. It has a width of about 4 miles and a length of about 8 miles. The greater part of the pool lies in the eastern parts of Tps. 17 and 18 N., R. 12 E..

The wells of the pool are started at or near the horizon of the Checkerboard limestone, which outcrops through the pool so that the wells in the eastern portion are started below the limestone and those in the western portion as much as 100 feet above the limestone.

Several sands are encountered in the wells of the Glenn pool and different ones of these are productive in different parts of the pool and in the outlying pools. The principal sands and their depths below the checkerboard limestone are as follows:

(1) Two shallow sands lie above the main producing sands. One of these is found at a depth of about 800 to 850 feet below the surface and the other about 100 feet lower. Both of these sands show some oil and gas locally, but are not important producers.

(2) The Red Fork sand is recorded at depths of from 1,275 to 1,400 feet. The thickness varies from 10 to 30 feet. This sand is an important producer, although it falls far short of the Glenn sand in this respect.

(3) The Glenn said is the great producer of both oil and gas. It is reported at depths of from 1,400 to 1,550 feet with majority of the logs showing its upper surface between 1,450 and 1,500 feet. The thickness as shown in the logs varies greatly in short distances, the extremes noted being 10 to 124 feet. Much of this apparent variation is due to the fact that many of the wells stopped before reaching the bottom of the sands, although there is almost certainly considerable variation in the thickness. The gas is usually found in the upper portion of the sand and the oil lower down. A strong flow of salt water is often encountered at the bottom of the sand. This sand is correlated with the Bartlesville sand of the pools farther north by many of the drillers.

(4) A few logs show a sand which is called only the stray sand at a depth of about 1,650 feet. The thickness is recorded as 35 to 40 feet.

(5) The Taneha (Squaw) sand is encountered at about 1,750 feet. The thickness varies from 10 to 50 feet.

(6) The Rhodes or Dutcher said lies about 100 feet below the Squaw sand.

(7) The Sapulpa or Mounds sand is shown in the logs of some of the deeper wells. The depth is about 2,350 feet and the thickness 10 to 40 feet.

The structure of the Glenn pool is very gentle. The surface shows only a terracing while the sub-surface structure as determined

on top of the Fort Scott limestone show only anticlines or "noses" plunging to the west or northwest and without closure to the east.*

It is probable that much of the accumulation is due to variations in the thickness and texture of the sands. The variation in the thickness of the Glenn sand in particular is extreme and Hutchinson (Bull. Okla. Geol. Survey No. 2) states that a series of carefully kept logs extending across the pool shows that the sand thins rather rapidly in both directions from the middle of the pool. This sort of a body of sand would give the arched effect of an anticline without revealing itself at the surface. (See fig. 9.)

The average initial production of the Glenn pool cannot be given accurately for the years previous to 1909, since the statistics are combined for the whole Creek Nation. The average of the Glenn pool was undoubtedly higher than that of the whole Creek Nation, which was 383.2 barrels in 1906, 277.9 barrels in 1907, and 146.1 barrels in 1908. The average initial production of the pool proper in 1909 was 78 barrels, and in 1910 was 62.6 barrels.

The well record for the Sapulpa district, including the Glenn, Mounds, Red Fork, Sapulpa, and Taneha pools, and the development near Tulsa, since 1909, is given in the following table. During these years the Taneha pool, the northern extension of the Glenn, has been the most active and has furnished over three-fourths of the development.

WELL RECORD OF SAPULPA DISTRICT, 1909-1916.

	Wells Completed				Initial Production	
Year	Total	Oil	Dry	Gas	Total	Average
1909	472	422	39	11	49,555	117.4
1910	391	357	21	13	36,575	102.5
1911	223	184	37	2	16,566	90.3
1912	698	457	147	94	25,279	55.3
1913	989	740	186	63	31,595	42.7
1914	1,195	872	252	73	56,920	65.3
1915	575	413	108	54	20,934	50.7
1916	988	781	140	67	49,268	63.1

The total production of the Glenn pool by months from its opening to the end of 1916 is shown in the following table:

TABLE SHOWING THE PRODUCTION OF THE GLENN POOL BY MONTHS

Month	1907	1908	1909	1910	1911
January	385,939	1,796,461	1,362,602	1,745,206	1,099,192
February	572,414	1 897,054	1,410,878	1,543,660	967,924
March	1,084,636	2,098,411	1,543,463	1,974,514	2,584,464
April	1,716,079	1,968,761	1,467,179	1,674,709	1,570,947
May	1 9[illegible]3 [illegible]26	1 [illegible]3[illegible] [illegible]1[illegible]	1,590,[illegible]30	1,676,[illegible]66	1,069 863
June	1,971,387	1,051,045	1,809,989	1,573,578	958,519
July	1,922,387	1,914,134	1,856,524	1,557,869	965,122
August	2 003 607	1,770,819	1,699,486	1,609,702	981,946
September	2,309,205	1,639,252	1,670,167	1,593,986	937,886
October	2,441,662	1,832,933	1,602,988	1,521,794	969,247

*Smith, C. D. The Glenn oil and gas pool and vicinity. Oklahoma. (Bull. U. S Geol. Survey No. 541, pp. 42-44, 1914.)

November	1,971,595	1,404,234	1,539,342	1,400,118	864,519
December	1,625,127	1,491,998	1,393,392	365,412	910,489
Total	19 926.995	20,494,313	18,946,740	19,236,914	13,880,118
Month	1912	1913	1914	1915	1916
January	882.383	792.336	839,483	464,627	528.265
February	867.566	718,850	769,809	421,922	614,390
March	924,144	807,022	871,334	459,546	838,580
April	898,527	823,645	849,316	455,184	562,855
May	927.182	850,607	897,397	508,786	657,389
June	816,028	816,789	852,901	462,224	650,594
July	880,906	787,274	828,350	555.222	530 413
August	927.675	734.476	535,027	555,514	556,107
September	794,958	773,847	431,051	518,546	579,463
October	921,736	817,628	584,178	534,608	593,220
November	768,254	753,115	604,397	520,012	646,137
December	886,157	794.551	614,346	541,347	524,561
Total	10,495,518	9,469,870	8,677,589	5,993,628	7,281,979

Smaller pools in the vicinity of Glenn pool—The development near Red Fork in T. 19 N, R. 13 E., and that near Jenks in T. 18 N., R. 13 E., is similar in every way to the Glenn pool, with which they are practically continuous, and may be considered as belonging to that pool.

Sand Springs pool—This development is principally of gas. It is located in the central T. 19 N., R. 11 E. There are a few oil wells in this township but the oil production is not important.

Leonard pool—A small pool is located about one mile south of Leonard in Sec. 33, T. 17 N., R. 14 E. The pool had some fairly large wells, one being reported at 1,200 barrels. The most active development was in 1916 and 1917. The pool proved to be spotted, and of small area.

Bixby pool—There is considerable development in Tps. 16 and 17 N., R. 13 E., in the vicinity of Bixby. The principal pool and the one ordinarily known as the Bixby pool is the northeastern part of T. 16 N., R. 13 E. Oil wells having as high as 700 barrels have been reported. The production varies from 1,600 to 2,100 feet in depth. The territory is spotted and there are many dry holes which separate the area into several small producing areas.

Broken Arrow pool—A long narrow strip of oil production extends from the E. ½ sec. 22, T. 18N. R. 15 E., southeastward to sec. 8, T. 17 N., R. 15 E., a distance of about 5 miles. The pool averages about 1 mile in width, but through most of its length is narrower than that. The initial production is small, not averaging more than 50 or 60 barrels per day. The production comes from a depth of about 1,300 feet.

Bristow pool—In the vicinity of Bristow and Kelleyville, southwest of Sapulpa there is some scattering development which may be called the Bristow pool. Most of this development is in the north-central part of T. 15 N., R. 9 E., where there are several gas wells of capacities ranging from 2,000,000 to 5,000,000 feet per day and a few small oil wells.

Two small pools are located near Kelleyville, one lying principally in sec. 2, T. 16 N., R. 10 E., and one in sec. 5, T. 16 N. R. 11 E.

OKMULGEE DISTRICT.

(By C. Max Bauer, Consulting Geologist, Okmulgee, Okla.)

Location and Area—The Okmulgee district is located in east-central Oklahoma and lies largely in Okmulgee county. The city of Okmulgee lies near the center of this district. The area comprised in this field is about 30 miles north and south and 30 miles east and west, or about 900 square miles, including ranges 10 to 15 east and townships 11 to 16 north. The district contains more than 40 distinct pools, which produce oil and gas. The principal producing areas are shown in fig. 74, but the production is so scattered that it is impossible to include all of it, without lining in the whole county.

Historical geology—The stratified rocks exposed in the Okmulgee district belong to the lower part of the Pennsylvanian system and include from the lowest exposed rocks to the highest, the Winslow formation, the Senora formation, the Calvin sandstone, the Wetumka shale, the Wewoka formation, the Holdenville shale, the Seminole conglomerate, the Checkerboard limestone, and overlying shales and sandstones of the Tulsa group.

The Checkerboard limestone is perhaps the most distinct stratigraphic marker in this district. It is known in the city of Tulsa and its outcrop con be traced southward through Jenks, Glenn Pool and Mounds to the southwest quarter of sec. 17, T. 14 N., R. 11 E. It is also found outcropping south of Okfuskee postoffice in T. 13 N., R. 10 E. The character of the other formations will be described more fully under the subject of stratigraphy. It will be sufficient to state here that they represent for the most part shallow water deposition in a basin connected with the sea, subject to rapid currents and sudden changes in the location of the currents carrying the sediment, with the exception of the epochs represented by the Henryetta coalbed and the Grave Creek coalbed.

Fossils are abundant at several horizons, particularly just above the Henryetta coal in the Senora formation, in the shale beds of the Wewoka formation, in the limy shales of the Holdenville group and in the Checkerboard limestone. The fossils of the Checkerboard limestone are not easily obtained as they are imbedded in the hard rock, although they seem to be well preserved.

Stratigraphy—As stated above, the series of sedimentary rocks outcropping in this district is composed almost entirely of shale and sandstone. A careful study of this series reveals the fact that few of the beds extend more than a few miles along their strike. This may be due to the small size of the basins in which they were deposited, or to the rapidly shifting currents of the depositional

basin, or to the shapes of the basins and the orientation of their short axes with the strike of the beds, i. e., it seems likely that the sandstone lenses are elongated parallel with the ancient shore-lines, which elongation now happens to run at right angles to the present strike. Thus the outcrops of the beds exposed are only cross sections parallel to their short axes. This latter explanation seems to fit the conditions in most cases, and because of these conditions, measured sections in one part of the field will not correspond to measured sections in another part of the field, and indeed they

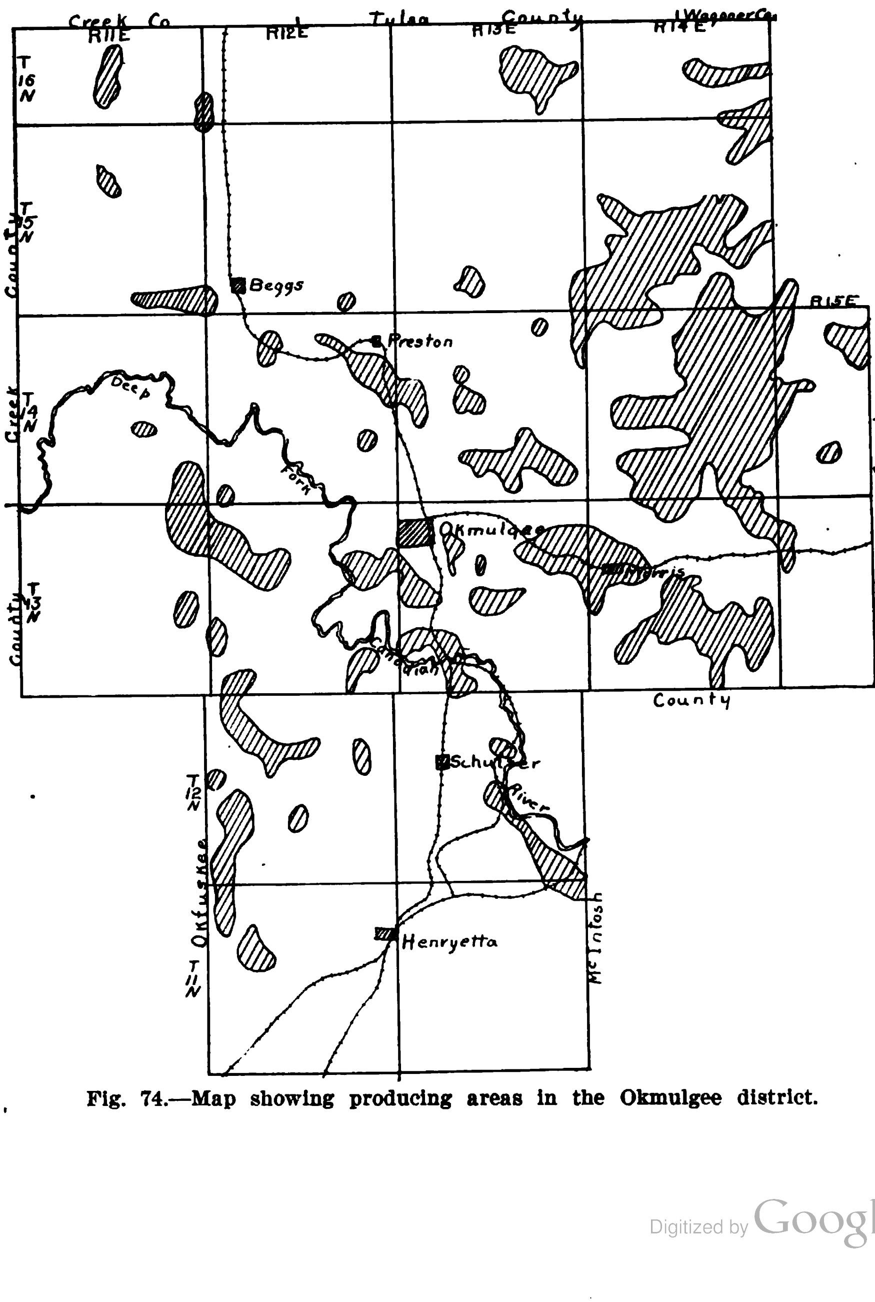

Fig. 74.—Map showing producing areas in the Okmulgee district.

can be used only locally for correlation purposes. There are, however, a few beds which can be traced for long distances along their outcrops. Three such beds, known as key rocks, are the Checkerboard limestone, a prominent sandstone in the middle part of the Wewoka formation, and the basal Wewoka sandstone. The Seminole conglomerate is another such bed but it cannot be traced northward farther than the vicinity of Beggs.

An accurate description of each of the various formations as named by J. A. Taff in the Coalgate folio of the U. S. Geological Survey is difficult owing to the fact that the top and bottom of these formations are not well defined and the formations are so much alike or grade northward into groups which are so similar that there is not sufficient reason for dividing them, i. e., on the whole, each formation is a group of sandstone and shale beds which, if taken over their entire extent, are very similar in their characteristics. However, the formations such as the Senora, Calvin, Wetumka, Wewoka, Holdenville, Seminole and the Checkerboard limestone are described below for the Okmulgee district.

The *Senora formation* outcrops in a northeast-southwest belt running through Henryetta, east of Shulter, through Morris, through T. 14 N., R. 14 E., and lies at the foot of Bald Hill. In the southern part of this district it is a series of sandstones and shales containing one workable bed of coal and several coal beds too thin to be worked at the present time. To the northeast, the sandstones grade into sandy shale and the shale and only one bed of coal is known to be present. The thickness of this formation is about 250 feet in the southern part of the area and diminishes to about 50 feet or less in T. 15 N., R. 15 E., and vicinity.

The *Calvin formation* is composed almost entirely of sandstone in the southern part of the district but from the center of T. 11 N., R. 12 E., northward it becomes more and more shaly and in the vicinity of Okmulgee it changes entirely to shale or is cut out by overlap of the Wetumka so that from a point about three miles northeast of the town of Okmulgee northeastward it contains no sandstone and indeed it seems probable that there is no Calvin present. Its maximum thickness is about 150 feet.

The *Wetumka formation* is essentially a shale formation and it maintains a thickness of about 120 feet from the southwestern part of the district to the vincinty of sec. 16, T. 14 N., R. 13 E. From this point northeastward it thins considerably. Its exact thickness northeast of the vicinity just mentioned cannot be determined as the formations below it are shale and have the same characteristics as the Wetumka. However, in T. 16 N., R. 15 E., less than 80 feet of shale occurs between the Winslow and Wewoka formations and is doubtless the representative of the Wetumka shale. It also contains many short lenses of sandstone.

The *Wewoka formation* is approximately 450 feet thick throughout this district. It is composed of thick massive and cross-bedded sandstones, interbedded with shale and sandy shale in alternating strata of about the same thickness. Its basal bed, as near as can be determined, extends for at least 15 miles along its outcrop, although it is a thin sandstone having a maximum thickness of about 6 feet. Another sandstone in the middle part of the Wewoka has been traced continuously more than 30 miles. This bed outcrops from the southeast corner of T. 11 N., R. 11 E., to the southeast corner of T. 15 N., R. 13 E., and very probably lies on top of Conjada mountain at Arkansas river. The upper portion of the Wewoka formation contains many cross-bedded sandstones which are very difficult to trace and, where they can be traced, they are so irregular that structural data based on them is of little value.

The *Holdenville formation,* like the Wetumka, contains many thin sandstones, although it is predominately a shale formation. In the vicinity of Beggs, the Holdenville contains some thin limestone members. At least two of these have been noted but owing to the fact that they are only a few inches thick they cannot be traced continuously. The upper part of the Holdenville as mapped by Taff in the Coalgate quadrangle has not geen traced through to the Okmulgee district and hence the thickness of this formation is not yet established in this area.

Overlying the Holdenville is a conglomerate which, in the opinion of the writer, will correlate with the *Seminole conglomerate* of sec. 17, T. 6 N., R. 8 E., as mapped by Taff. This formation has been mapped in reconnaisance from the extreme southwest corner of T. 13 N., R. 11 E., to a point in sec. 24, T. 15 N., R. 11 E., about two miles northwest of Beggs. The pebbles in this conglomerate are composed almost entirely of light-colored chert. In the western part of T. 13 N. R. 11 E., these pebbles have an average size of about one-eighth inch in diameter. To the northeastward the size of these pebbles diminishes to the size of sand grains in the vicinity of Beggs. Beyond this point the bed has not been distinguished from other sandstones in its immediate section. Its thickness is from 15 to 25 feet. This estimate includes the sandstone with which it is associated, the conglomeratic portion of the bed being often much thinner. The conglomeratic portions are in some places at the base, in others at the top, and in still other places the conglomeratic portions or lenses are within the sandstone. For this reason, it is very difficult if not impossible to map the top of this bed and obtain results that are valuable structurally except in a very general way.

Above the Seminole conglomerate in this district is a shale that averages from 100 to 120 feet in thickness. This shale is in turn overlain by the Checkerboard limestone. This limestone is remarkable for its persistent characteristics such as its thickness,

color, resistance to weather, peculiar fossil markings, jointing, etc. It was mapped in detail along its outcrop from the north side of T. 16 N., R. 12 E., to the southwest corner of T. 14 N., R. 11 E., or a distance of about 20 miles. It is a hard blue limestone averaging 4 feet in thickness and contains peculiar semi-circular markings caused by the presence of fossil brachiopods. Its weathered surface is usually a light cream color or a very light yellow. On weathering it breaks into blocks which are nearly cubical and are about four feet on each side. It outcrops usually in stream beds and very seldom on hills or ridges. This limestone is reported to outcrop near the town of Glenpool and also at the crossing of the Frisco and Midland Valley tracks in Tulsa. A shale belonging to the Tulsa group overlies the Checkerboard limestone and is in turn overlain by the sandstones of the Sapulpa group.

Structure: Structural features as revealed at the surface in the area west and northwest of the outcrop of the Calvin sandstone bear only a slight resemblance to the structures which are revealed by subsurface studies. Their significance, however, is important. East of the outcrop of Calvin sandstone the structure of the exposed rocks is believed to correspond more nearly to the structure of the producing sands.

There is a general thinning of the formations to the north and northwest, as well as considerable evidence of one or more overlaps in the formations in the lower part of the section here described. The highest overlap has been noted at the base of the Wetumka shale in T. 16 N., R. 15 E., where this shale is not over 80 feet thick and rests on the Winslow formation. Farther south, in T. 15 N., R. 15 E., shales and sandy shales appear which belong to the Calvin and Senora formations. And still farther to the south and southeast the Stuart shale, Thurman sandstone and Boggy shale appear in turn between the Calvin sandstone and the Winslow formation. The strike of the Winslow is northwest-southeast whereas the strike of the Calvin is northeast-southwest. Well logs not only indicate a gradual thickening of known strata toward the southeast but also seem to show the sudden appearance of new strata which are not strictly parallel to the beds higher in the section. For these reasons it seems probable that several overlaps may be present.

The major feature of the structure in the western part of the Okmulgee district is that of a northwestward dipping monocline with only slight variations from normal. The average dip of the strata towards the northwest is about 90 feet per mile or 1 degree. In places, this dip is as great as 150 feet to the mile and in other places it is as low as 50 feet to the mile. East and southeast of the outcrop of the Calvin sandstone the average dip is much less than it is to the west and northwest. In the eastern district,

the structure of the producing sands is more nearly parallel to that of the structure of the surface beds. The variation in structure between the surface beds and the producing sands in the western part of Okmulgee county is due partly to the thickening of the beds to the southeast, but is also due to the fact that the deeper strata were folded slightly before the younger beds were deposited. In other words, the folding was going on while the sediments were being deposited, or at intervals during the early Pennsylvanian period. Structural data based on producing sands show that anticlines, domes, synclines and basins exist at depth where the surface indicates only minor variations in dip. Many of the pools show the presence of faulting in the beds at a depth of 1,000 feet or more which is not discernible at the surface. So far, the faulting of surface rocks observed is of minor consequence. Faults, in the producing sands, with a throw of 10 to 100 feet are known in at least a dozen pools. These faults generally run in a southeast-northwest direction. The study of the sub-surface structures is very important in the guiding of drilling and production operations.

Producing pools—As stated previously, there are more than 40 producing oil and gas pools in the Okmulgee district. Many of these are well defined, others are not developed sufficiently or are so irregular in outline as not to be easily defined. Morris and Bald Hill were the first to be developed, the Booch sand pool of the Morris field having been discovered in 1904 and developed early in 1905. Bald Hill followed in 1906. Many of the early wells in this part of the county came in at 1,000 and 1,500 barrels. Recent completions, however, are rarely over 100 barrels daily production. Three or four sands are the principal producers in this part of the county. They are the Salt sand at about 800 feet, the Booch sand at 1,200 the Morris at 1,600, and the Leidicker at 1,800. Other deeper and intermediate sands have been productive locally.

Recent development has been most active in the western part of the district in Ranges 11 and 12 east. Here the Youngstown pool in secs. 25 and 36, T. 14 N., R. 11 E., the Thousand Acre Lake pool in secs. 23 and 26, T. 13 N., R. 12 E., and the Wilcox pool in secs. 35 and 36, T. 15 N., R. 11 E., have attracted wide attention and are producing large quantities of oil. Several new sands have been discovered in this district, among them a sand at 2,900 feet which is doubtless in the Fayetteville shale of the Mississippian system. There are five principal producing sands in the western part of the country. In the Youngstown field they lie at 1,750, 1,900, 2,300, 2,500 and 2,800 feet in depth. Many of the wells are coming in at 1,000 barrels daily production. The condition of development of the Youngstown and Thousand Acre Lake pools on March 15, 1919, are shown in figs. 75 and 76.

The following table gives the principal pools, their location, the year of first development, and the names and approximate depths of the principal sands in each pool.

Production of the Okmulgee district—The Okmulgee district has averaged over 10,000 barrels daily for many years. In the last two years it has gradually increased its production and in the month of February, 1919, the average daily production amounted to over 18,000 barrels. This was divided among the various pools as follows:

AVERAGE DAILY PRODUCTION OF POOLS IN OKMULGEE COUNTY FOR FEBRUARY, 1919.

	Barrels Daily
Mounds, Beggs and Youngstown	4,605
Hamilton Switch	2.487
Bald Hill and Booch Sand	4,987
Tiger Flats (including 1000 acre lake)	3,027
Morris	2,614
Shulter	208
Henryetta	206
Total barrels daily	18,134

This is one-twelfth of the total daily production of the entire State of Oklahoma.

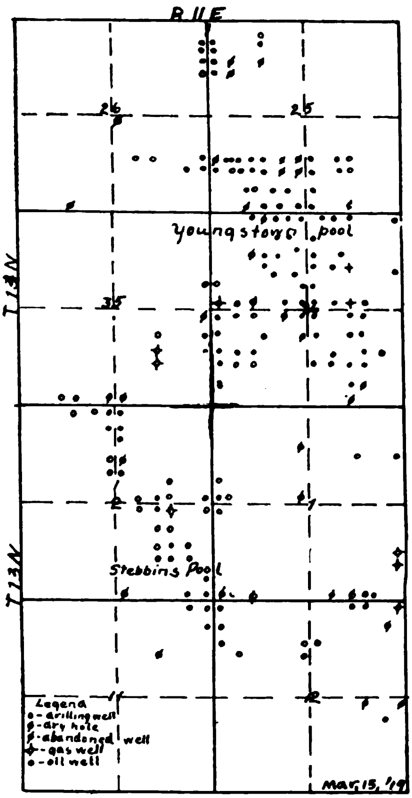

Fig. 75.—Map of Youngstown pool showing development.

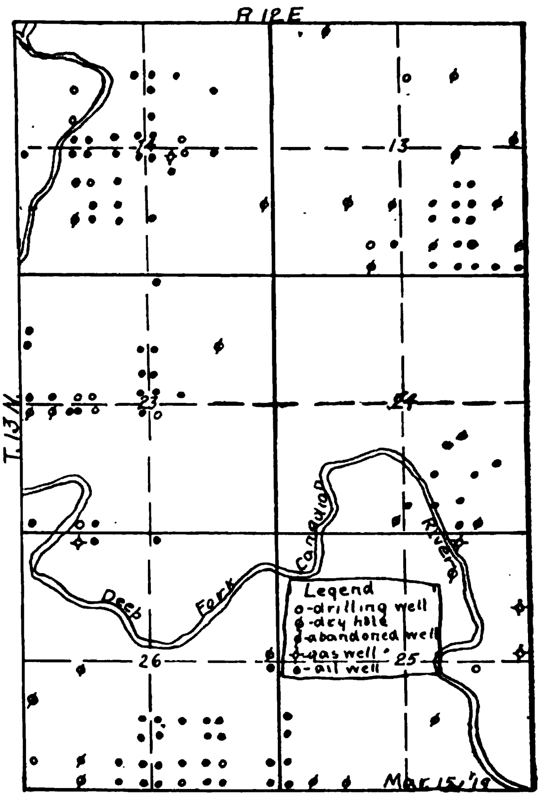

Fig. 76.—Map of Thousand-acre Lake pool showing development.

TABLE SHOWING PRODUCING POOLS IN THE OKMULGEE DISTRICT.

NAME OF POOL	LOCATION	Year of Develop-ment.	PRINCIPAL PRODUCING SANDS AND THEIR APPROXIMATE DEPTHS
Booch Sand	Sections 15, 16, 20, 21, 22, 23, 26, 27, 28, 34, 35, T. 13 N., R. 14 E.	1905	Salt sand 700, Booch 1200, Morris 1550, Glen of Morris 1650 Leidecker 1750.
Bald Hill	South Half, T. 15 N., R. 14 E.	1906	Salt sand 850, Booch sand 1210, Red Fork sand 1570, Glen of Morris 1725.
Tiger Flats	North Half, T. 12 N., R. 12 E.	1908	A number of producing sands.
Henryetta-Schulter	Sections 21, 22, 26, 27, 35, 36, T. 12 N. R. 18 E.	1909	Salt sand 700, Booch sand 1,200 sand 1,800.
Hamilton Switch	Sections 11, 12, 13, 14, T. 14 N., R. 12 E. and Section 18, T. 14 N., R. 13 E.	1911	Salt sand 1475, Booch sand 1950, Preston sand 2125.
Beggs	Sections 4, 5, 8, 9, T. 14 N., R. 12 E.	1910	Salt sand 1375, Booch 1750, Preston sand 2100.
Morris	Sections 11, 12, 13, T. 13 N., R. 12 E., and	1912	Salt sand 725, Booch sand 1225, Sand 1660, Sand 1850.
	Sections 7, 8, 18, 19, T. 13 N., R. 14 E.	1912	Salt sand 800, Booch sand 1340, Fields sand 1940.
Pine	Sections 27, 28, 34, T. 14 N., R. 13 E.		
Salt Creek	Sections 23, 24, 25, T. 13 N., R. 11 E.	1913	Salt sand 1700, Booch sand 2020, Gas sand 2375, Oil sand 2490.
Artesia	Sections 1, 2, 11, 12, T. 11 N., R. 11 E.	1915	Gas sand 800, Oil sand 1150.
French	Sections 8, 17, T. 11 N., R. 12 E.	1915	Salt sand 1,350, Oil sand 1620, Deep sand 2540.
T. 14 N., R. 14 E.	Scattered over most of T. 14 N., R. 14 E.	1915	Salt, Booch, Fields and Morris sands. Depths about same as in Morris field.
Council Hill	Sections 24, 25, 36, T. 13 N., R. 14 E.	1916	Salt sand 775, Booch sand 1320, Fields sand 1840, Sand 1920.
Major	Sections 10, 11, 16, T. 16 N., R. 13 E.	1916	Sand 1525, Sand 1600.
Luckey	Sections 18, 19, T. 13 N, R. 13 E.	1916	Salt sand 1240, Booch sand 1650, Sand 1975, Sand 2060.
Wigton	Sections 25, 26, 35, 36, T. 13 N., R. 12 E.	1916	Shallow sand 550.
Deep Fork	Sections 29, 32, 33, T. 13 N., R. 13 E.	1917	Salt 1350, Sand 1700, Sand 1900.

TABLE SHOWING PRODUCING POOLS IN THE OKMULGEE DISTRICT—(Continued.)

NAME OF POOL	LOCATION	Year of Develop-ment	PRINCIPAL PRODUCING SANDS AND THEIR APPROXIMATE DEPTHS
Mounds	Sections 9, 10, 15, 16, T. 16 N., R. 11 E.	1917	Glen sand 1850, Sand 2000, Sand 2200.
Natura	Sections 27, 34, T. 15 N., R. 13 E.	1917	Salt sand 1225, Booch sand 1690, Sand 1950.
Cole	Sections 3, 4, 9, 10, 11, T. 14 N., R. 15 E.	1917	Salt sand 600, Booch sand 1000, Sand 1210, Sand 1530.
Eram	Section 13, T. 13 N., R. 14 E., and	1917	Salt sand 700, Booch sand 1200, Gas sand 1860.
	Sections 7, 18, T. 13 N., R. 15 E.	1917	Salt sand 600, Booch sand 1180, Sand 1583, Sand 950.
Shepard	Sections 11, 14, 15, T. 13 N., R. 15 E.		
Twin State	Sections 29, 30, T. 12 N., R. 12 E.	1917	Sand 1560, Sand 1900.
Youngstown	Sections 25, 26, 36, T. 14 N., R. 11 E.	1918	Salt sand 1750, Booch sand 2000, Youngstown 2300, Deep sand 2800.
Wilcox	Sections 35, 36, T. 15 N., R. 11 E.	1918	Sand 2300.
Brookens	Sections 9, 16, T. 13 N., R. 12 E.	1918	Sand 2100.
Big Gas	Sections 6, 7, 8, T. 13 N., R. 12 E.	1918	Sand 1750, Sand 2100.
Barbara	Section 31, T. 14 N., R. 12 E.	1918	Sand 2310.
Stebbins	Sections 1, 2, 11, 12, T. 13 N., R. 11 E.	1918	Salt sand 1750, Sand 2320, Sand 2490, Deep sand 2800.
Newman	Section 21, T. 12 N., R. 12 E.	1918	Sand 2365.
1000 Acre Lake	Sections 13, 14, 22, 23, 26, T. 13 N., R. 12 E.	1918	Salt sand 1300, Booch sand 1700, Glen of Morris 2100, Deep sand 2950.

And many other small pools

NOTE—No attempt at accurate correlation of sands has been indicated in this table.

The following table gives the well record for the Okmulgee district from 1911 to 1916 inclusive, as nearly as it can be compiled from the United States Geological Survey reports.

WELL RECORD OF OKMULGEE DISTRICT, 1911-1916.

	Wells Completed				Initial Production	
Year	Total	Oil	Dry	Gas	Total	Average
1911	203	127	52	24	13,750	108.4
1912	531	315	171	45	36,551	116.0
1913	1403	887	396	120	59,387	67.0
1914	1240	909	276	55	64,243	70.6
1915	530	347	154	29	18,340	52.5
1916	949	645	257	47	27,295	42.3
1917	Statistics not available.					
1918*	1555	1027	381	147	81,283	79.1

*Oil and Gas Journal.

MUSKOGEE DISTRICT.

The Muskogee district, as considered here, includes Muskogee and Wagoner counties, and the extreme southeastern part of Rogers county. The following pools may be distinguished: Muskogee, Wainwright, Boynton, Cole, Haskell, Inola, Coweta and Stone Bluff. There has been considerable drilling over the territory and several wells outside the pools mentioned above have shown some oil and gas but have led to no important developments.

The geology of this district varies somewhat from that of the fields to the northwest. The wells start below the horizon of the Fort Scott (Oswego) limestone and penetrate the shales and sand-

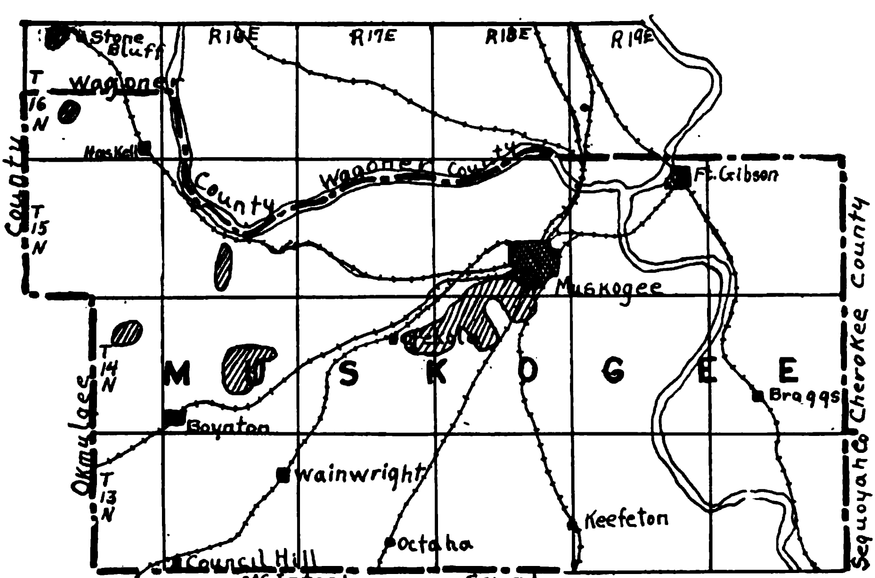

Fig. 77.—Map showing producing areas in the Muskogee district.

stones of the Winslow formation. There is a strong possibility that some of the production is from below the Pennsylvanian but the underground geology of the area is very uncertain.

Muskogee pool—The Muskogee pool extends southwest from the city, between the M., O. & G. and M., K. & T railways, for a distance of about six miles. The wells in the northeastern part of the pool, near the townsite, reach the productive sand at a depth of between 1,000 and 1,100 feet. The occurrences in the southwestern part of the pool are very erratic, some wells being over 1,000 feet deep and others striking good pay at considerably less depth. In any case, however, the wells extend beyond the depth which should carry them through the Pennsylvanian rocks according to the thickness given by Taff in the Muskogee folio and should penetrate the Mississippi lime. The logs do not indicate that this is true, as all the rocks encountered in the lower parts of the wells are sandstones and shales. It is probable that the actual thickness of the Winslow is greater in this region than the thickness obtained by Taff by measuring across the outcrop.

The development of the pool began on the townsite in 1904 and a small pool was outlined. This pool, known as the townsite pool, was soon exhausted and the wells abandoned. The development to the southwest began in 1906 and has been fairly constant ever since. The field is very spotted and the percentage of dry wells is rather high. There are also many gas wells irregularly distributed through the field. The well record of the pool from 1909 to 1913 is as follows:

WELL RECORD OF MUSKOGEE POOL.

	Wells Completed				Initial Production	
Year	Total	Oil	Dry	Gas	Total	Average
1909	129	79	41	9	3,245	104.4
1910	171	123	43	5	16,640	135.3
1911	117	81	34	2	6,965	86.0
1912	38	12	24	2	293	24.4
1913	100	60	31	9	1,569	26.1

Since 1913 the statistics for all the pools in this district, except Inola, have been combined by the United States Geological Survey. These statistics are given at the end of the discussion of the district.

Wainwright pool—The development near Wainwright consists principally of gas wells of moderate capacity with a few small oil wells. The pool is of little importance.

Boynton pool—The Boynton pool is located about four miles northeast of Boynton in secs. 15, 16, 21, 22 and 28, T. 14 N., R. 16 E. Development was begun in May, 1914, and by January, 1915 there were 13 producing oil wells, 4 gas wells and 3 limiting dry holes. Production is found at depths of 1,350 to 1,640 feet with the best pay between 1,510-1,545 feet. The earlier wells were fairly small producers, 12 to 150 barrels initial production, but more recently

much larger wells have been had. One brought in in September 1915, was credited with an initial production of 1,800 barrels. The structure of the pool is said to be anticlinal with a pronounced narrowing or pinching to the northeast, practically forming a dome. The greatest production is from the narrowed, northeast portion of the structure. The limits of the pool are well defined. The production reached 8,000 barrels per day but had declined to 5,500 by the beginning of 1916.

The Cole or northwest Boynton pool—This pool is located about six miles west of the one just described, with best wells in sec. 11, T. 14 N., R. 15 E. The producing sand is found at about 1,610 feet. The initial production was as high as 300 barrels daily per well.

Haskell pool—This pool may be regarded as an extension of the Bald Hill pool to the southwest in Okmulgee county. The Haskell development lies in T. 16 N., R. 15 E. Four sands ranging in depth from 800 to 1,960 feet are productive of oil or gas or both. The oil wells are of moderate initial production, most of them being about 100 barrels. Gas wells of up to 25,000,000 cubic feet daily capacity were found. The field has shown little of interest in the past year or two.

Inola pool—The Inola pool is situated in secs. 3, 4, 9 and 10, T. 19 N., R. 19 E., in southeastern Rogers county. The pool was opened in 1913, was developed very rapidly and reached its maximum production early in 1914. By April of that year it had declined to a daily production of about 2,000 barrels. The pool had unusually large producers, for shallow wells, up to 1,100 barrels daily initial production being reported. The greater part of the production came from depths of 600 feet or less. There has been no development of particular interest in the past two or three years.

Coweta pool—Considerable attention has been attracted from time to time by the bringing in of moderate sized wells near Coweta in western Wagoner county and near Broken Arrow to the west in Tulsa county. The area has proven to be very spotted and the pools have not achieved much importance. Several sands from 600 to 1,350 feet were encountered. The wells were small, most of them having less than 100 barrels initial production. The Coweta development in principally in T. 17 N., Rs. 15 and 16 E.

Wagoner pool—This development consists of several small pumpers in T. 18 N., R. 18 E., about 5 miles northwest of Wagoner. The wells start only a few hundred feet above the Mississippi lime and the production is at the very base of the Pennsylvanian or possibly in the Mississippian.

Stone Bluff pool—This pool is located near the Midland Valley railroad about half way between Muskogee and Tulsa. Most of the

production is from sec. 5, T. 16, R. 15 E. The field was opened late in 1915; by January 1, 1916, had 5 producing wells; and by February 1, 9 producing wells with a daily production of between 5,000 and 6,000 barrels, and by March 1, the production had increased to about 12,000 barrels per day, and a few days later to 13,000 barrels. The field was quickly defined and its area was very small. The production had declined to 7,500 barrels by April 1, 1916, and has continued to decline since that time.

The well record for the Muskogee district since 1913, not including the Inola pool, is as follows:

WELL RECORD OF MUSKOGEE DISTRICT.

Year	Wells Completed Total	Oil	Dry	Gas	Initial Production Total	Average
1914	380	200	139	41	7,532	32.7
1915	623	313	237	68	39,077	122.9
1916	911	583	268	60	56,581	97.1
1917	Separate statistics not available.					
1918*	910	474	335	101	48,888	103.1

*Oil and Gas Journal—Includes Rogers County production.

PAWNEE COUNTY DISTRICT.

The development in Pawnee County is in the extreme northeast part near Cleveland, and is known as the Cleveland field or pool. The development of this pool began rather early in the history of the oil industry of the state and, with some halts, has continued until the present. The early development was in the town of Cleveland and the immediate vicinity and the more recent has been to the south and southeast of the town. The developments farthest south and east are known as the Olney and Lauderdale pools.

The rocks of the region consist of sandstones and shales of the upper part of the Pennsylvanian system and the wells are started near the horizon of the Elgin sandstone. The production is from sands at about the same level as the sands of the pool farther north and east and also from sands higher in the section.

The following description of the pool about the end of 1909 is given by Hutchinson in Bulletin No. 2 of the Oklahoma Geological Survey:

The first well drilled was on the Bill Lowery farm, just south of the townsite and was known as "Uncle Bill No. 1." The enterprise was promoted by local capital and resulted in a paying well at 1,615 feet. Development followed rapidly and almost every town lot was soon drilled. The city council had to pass an ordinance forbidding the drilling of wells on the rear ends of business lots on Main street. The principal part of the field was found south of town in sections 16 and 17, although sections, 18, 20 and 29 have also proved profitable territory.

Two sands were discovered, known as the Cleveland sand and Kelso sand. The Kelso sand, found on the Kelso farm southwest of Cleveland, is above the Cleveland sand and in early development of the Kelso pool drilling ceased on reaching that horizon. Owing to the fact that at the time operations began in

Cleveland pool there was no law fixing the minimum distance at which oil wells should be drilled, development in this field resulted in great waste to operators. Wells were often drilled on adjacent town lots, so near each other that there was hardly room to build the rigs. In such cases many wells were soon exhausted and casings pulled without having repaid the initial cost. Perhaps nearly one-half the wells on the townsite have already been abandoned.

The limits of the pool have been pretty well defined, for several years by a series of dry holes drilled around its margin. The rock pressure has decreased to considerable extent, but the field is still a good steady paying one.

During the year 1909 there were 21 wells drilled in the Cleveland field only one of which was dry and but two produced gas. The other eighteen were oil wells with an initial production of 1,095 barrels daily.

Since 1909 the development has carried the field farther to the southwest. The finding of deeper productive sands has, however, been the principal factor in prolonging the life of the field. The productive sands of the pool and their depths from the surface are given by Robt. H. Wood in Bulletin 531 B. of the U. S. Geol. Survey as follows:

PRODUCING OIL SANDS IN THE CLEVELAND FIELD.

Sand	500
Sand	1000
Layton	1300
Sand	1400-1500
Cleveland	1570-1700
Skinner	2200
Bartlesville	2400
Tucker or Meadows	2600-2800

The sands mentioned above, however, are not found in all the wells and where encountered are not always productive.

The well record of the field is given in the following table:

WELL RECORD OF PAWNEE COUNTY, 1908-1918.

	Wells Completed				Initial Production	
Year	Total	Oil	Dry	Gas	Total	Average
1908	22	14	7	1	455	32.5
1909	28	23	3	2	1,865	81.1
1910	13	10	2	1	713	71.3
1911	165	129	31	5	22,100	171.3
1912	205	130	68	7	5,463	43.4
1913	262	187	68	7	15,787	84.4
1914	111	77	27	7	3,905	50.7
1915	76	47	26	3	1,328	28.3
1916	197	140	46	11	6,058	43.3
1917*	235	180	44	11	20,753	115.3
1918*	205	130	68	7	5,643	43.4

*Oil and Gas Journal.

Considerable drilling has been done in Pawnee county outside of the Cleveland pool but with only moderate success. Some oil and gas have been developed near Hallett and some good gas wells have been brought in near Maramec, but these cannot be considered as important pools. In 1916 a small oil pool was developed near Jennings in Sec. 22, T. 20N, but it has failed to develop into anything of importance. The entire county has been pretty well tested and the probabilities of any important production are small.

The producing areas near Cleveland are shown with those of Osage county in fig. 78.

OSAGE COUNTY.

(By E. P. Hindes.)

Osage county is located in the north tier of counties and a little east of the center of the state. It extends from T. 20 N., to T. 29 N., inclusive, and from R. 2 E. to R. 12 E., inclusive. It consists of 46 entire townships and parts of 35 others. The entire area is approximately 2,350 square miles, or 1,500,000 acres. The county has the same area and limits as the Osage National Reservation.

The Osage National Reservation was created by Act of Congress June 15th, 1872. This act states that a tract of country west of the 96th meridian, bounded "on the east by the 96th meridian, on the south and west by the north line of the Creek country, and the main channel of the Arkansas river, and on the north by the

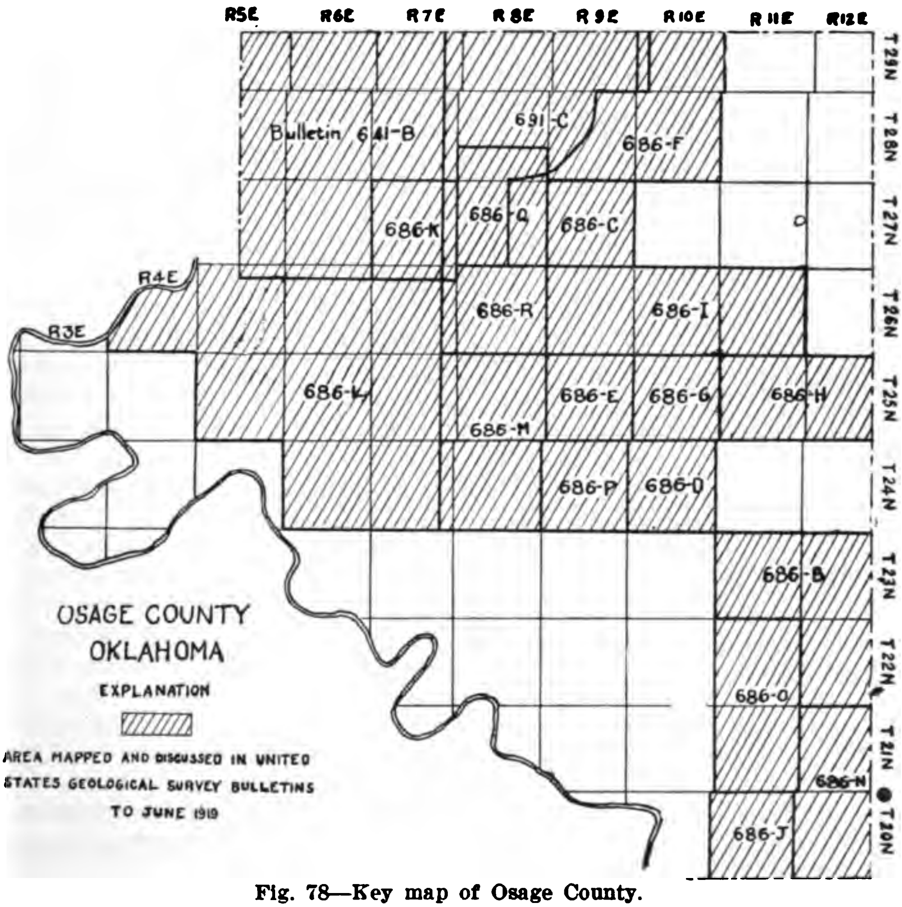

Fig. 78—Key map of Osage County.

south line of Kansas" should be assigned as the permanent home of the Osage Indians.

The Oklahoma State Constitution expressly stated that the reservation should constitute a single county until all the lands were allotted, after which the legislature could sub-divide it. As it now stands Osage county is the largest civil division in the state.

History of Mineral Right Leasing.

An act of Congress, February 28, 1891, provided that certain Indian lands could be leased for mining purposes for a period of ten years in such quantities and upon such terms and conditions as the agent in charge of the Reservation might recommend, subject to the approval of the Secretary of the Interior. By virtue of the act a lease was executed in 1896 to Edwin B. Foster, covering the whole of the Osage Reservation, about 1,500,000 acres. The lease expressly ran to the grantee and his assignees and recognized the right in said grantee to sub-lease any portion thereof.

The same year the Phoenix Oil Company was formed and took over all the interests of Edwin B. Foster. This company immediately drilled a number of wild cat wells in the southeastern portion of the Reservation, which were the first producing wells in Oklahoma.

In 1900, the Osage Oil Company was formed, which received an assignment of a portion of the lease held by the Phoenix Oil Company, being described as "six miles north and south by ten miles east and west" lying near the east line of the Reservation, westerly from Bartlesville, Indian Territory.

In 1902 the Indian Territory Illuminating Oil Company was formed and all the leases held by the Phoenix Oil Company and the Osage Oil Company were transferred to the new company. By the end of 1914 the Indian Territory Illuminating Oil Company had sub-leased 680,000 acres of the whole Reservation.

The original lease to Edwin B. Foster would expire in 1906 so by Act of Congress March 3, 1905, the leases on the 680,000 acres only, or the acreage which had been sub-leased by the Indian Territory Illuminating Oil Company were renewed for a period of ten years. The lease on the remainder of the Reservation was permitted to expire. This action left the Indian Territory Illuminating Oil Company with only 2,060 acres, however, this acreage was considerably increased later by purchase from sub-lessees.

By Act of Congress, June 28th, 1906, all the lands belonging to the Osage Tribe of Indians were allotted among the members of the tribe, giving to each his or her full share. The same act provided that all the oil, gas and mineral rights were reserved to the tribe as a tribe in their tribal relations for a period of twenty-five years, and recognized the existing leases.

During the period between the granting of the first lease to Edwin B. Foster in 1896 and May 31, 1917, only three leases were executed. One of these covered a block of acreage in T. 23 N., R. 8 E., on which is located the Hominy (section 8) field, a block in Tps. 21 and 22 N, Rs. 7 and 8 E, on which is located the Boston pool, and a block in T. 24 N., R. 9 E.

On May 31, 1917, was held the first of a series of auction sales for the sale of leases. From this date until June 6, 1919, seven sales were held, the dates being as follows: May 31, 1917; Nov. 12, 1917; Feb. 14, 1918; May 18, 1918; Nov. 9, 1918; March 5, 1919, and June 6, 1919. At these sales the oil rights on one-hundred and sixty-acre tracts were offered to the highest bidder. The tracts were well scattered over the portion of the county east of Range 7, except at the last two sales when a very few tracts west of Range 8 were sold. The largest of these sales in point of acreage was that of May 18, 1918 when 321 tracts were sold, and the largest in point of bonus money paid was that of June 6, 1919, when the sale amounted to over $5,000,000.00. However, at this sale the gas rights on a large tract in the western portion of the county were sold. The highest price paid for a single one-hundred and sixty-acre tract was $600,000.00 and was paid for the SW. ¼ sec. 17, T. 27 N., R. 8 E. The highest price paid for gas acreage was $4.00 per acre. Up to and including the sale of June 6, 1919, approximately 350,000 acres out of a total in the county of 1,500,000 acres had been leased for oil. The entire county is now leased for gas.

Topography and Drainage.

The surface of Osage county in a broad sense is that of a level plain. However, a well developed drainage system has produced a maximum relief of approximately 250 feet.

The eastern half of the county lies in the Sandstone Hills region. The rocks exposed at the surface are practically entirely sandstones and shales, with a few limestones. In the western half of the county the rocks exposed are practically entirely limestones and shales with a few sandstones. Over the entire county the lithologic character and structure of the rocks are very closely reflected in the topography of the region. Both the limestone and sandstone formations characteristically form well-defined escarpments with steep eastern slopes, and in many cases long, gentle dip slopes to the west. In a few localities local folding is reflected in the topography giving west facing escarpments and dip slopes to the east.

Over most of the county erosion is active and gulches and valleys are being vigorously excavated. The resultant debris is carried away by the streams before it has a chance to accumulate in any great quantity, hence the valley sides are comparatively steep, however, in a few localities broad shale valleys have developed.

The drainage of the county is to the southeast. The extreme western and southwestern portion of the county is drained by Arkansas river and streams tributary to it. The remainder of the county is drained by the streams tributary to Verdigris river, the principal ones being Hominy creek, Bird creek, Sand creek and Caney river.

Geology.

The rocks exposed at the surface in Osage county are all of sedimentary origin and are of late Pennsylvanian and early Permian age. The contact between the Pennsylvanian and Permian was mapped by J. W. Beede and the results published in Oklahoma Geological Survey Bulletin. He shows this contact as entering Oklahoma from Kansas near the east line of T. 29 N., R. 6 E., and extending in an irregular line a little west of south across the county and crossing the Arkansas river near the west line of T. 24 N, R. 5 E. The sediments of the county are almost entirely marine and were deposited in comparatively shallow water.

Stratigraphy.

The formations exposed at the surface in Osage county are approximately 2,800 feet thick. Of this thickness 2,250 feet are of Pennsylvanian age and 550 feet of Permian age.

The Pennsylvanian formations exposed in the county from the lowest to the highest are as follows; about 120 feet of the upper Coffeyville formation; Hogshooter limestone; an interval of unnamed sandstone and shale varying from 75 to 300 feet in thickness; Dewey limestone; Wilson and Buxton formations; Pawhuska limestone; and an interval of alternating limestones and shales, with a few sandstones, having a thickness of approximately 700 feet. Included in this later series is the Cryptozoon, Stonebreaker, Foraker, Red Eagle and Neva limestones.

The formations of early Permian age from the lowest to the highest are as follows: The Council Grove, Chase and Marion formations of the Kansas section and included in these formations are the Cottonwood, Crouse, Wreford, Ft. Riley, Winfield and Herington limestones.

A more detailed description of the formations exposed in the county is given in a preceding section on the Geology of Oklahoma and also in the United States Geological Survey Bulletins as shown in fig. 78.

Structure.

Osage county is located on the southwest flank of the Ozark uplift. The structure of the area is in general that of a gentle northwest dipping monocline. The average dip is about thirty feet

to the mile. The general monoclinal structure, is, however, broken in many places by local folding and faulting, which form rather well defined bands across the county. The folded areas are conspicuously present in the eastern and central portions of the county, whereas the monoclinal structure of the western portion is practically unbroken.

One of the largest folds in the county is the Meyers dome, located just east of Meyers station on the Midland Valley Railroad. This fold has a reserve dip of approximately seventy feet. Two other folds of about the same size are located northwest of Hominy, on one of which is the Section Eight oil field.

The faults have a general northwest, southeast trend and are seldom ever one mile long. The vertical displacement ranges from a few feet to a maximum of approximately 150 feet.

Detailed information in regard to the structure of the county is given in the United States Geological Survey Bulletins shown on fig. 78.

Production.

As a producer of oil and gas Osage county has proven to be one of the most prolific areas in the Mid-Continent field. The method of leasing has greatly retarded development in the county but even with this handicap it has made rapid progress. There has been no development to date west of Range 7, due to the fact that the area has not been leased. The developed areas east of Range 6 are shown on Plate III. From this plate it can be readily seen that a large portion of this area has been proven productive. From a geological standpoint there is probably not another area of equal size in the Mid-Continent field that has as large a percentage of favorably located acreage. Of the entire number of tracts that have been sold one out of three has proven productive.

At least ten producing horizons are found underlying the county. From the shallowest to the deepest they are: Layton; Cleveland; Big Lime; Peru; Oswego; Wheeler, Bartlesville; Tucker; Burgess, and Mississippi lime. The Bartlesville sand is one of the most extensive laterally and is generally considered the best producer in this portion of the Mid-Continent field.

While the western portion of the county has not been tested it is a very favorable area and will no doubt prove productive. It looks especially favorable for gas and the recent completion of some large oil wells, sec. 17, T. 27 N., R. 8 E., which was formerly considered a gas area, proves that this portion of the county also has great possibilities as an oil producer.

The following list gives the names by which the producing areas are generally known, with their location, the productive horizons and the approximate average initial production.

NO.	FIELD—	LOCATION.	PRODUCING SANDS AND APPROXIMATE DEPTHS.		APPROXIMATE INITIAL PRODUCTION
1.	South Elgin	Secs. 15, 16, 17, 20, 21, T-29-N, R-9-E.	Peru	1,500 ft.	Barrels Oil.
2.	Chautauqua	Secs. 14, 15, 16, 17, 21, 22, T-29-N, R-11-E. Secs. 26, 27, 33, 34, 35, 36, T-29-N, R-19-E. Secs. 1, 2, 3, 10, 11, 12, 14, 15, 22, 23, 26, 27, 34, 35, 36, T-28-N, R-10-E.	Peru (or Whiting) Peru	1,000 ft. 1,050 ft.	10-15 Barrels Oil (Some Gas.) 125 Barrels Oil.
3.	Pond Creek	Secs. 1, 2, T-27-N, R-10-E.	Mississippi Lime	1,600 to 1,900 ft	5 Million Cubic Feet Gas. 30 Barrels Oil.
4.	Pearson	Secs. 16, 17, 18, 19, 20, 21, 22, 28, 29, 30, T-27-N, R-8-E.	Shallow Gas Sand Gas Sand Mississippi Lime	800 ft. 1,400 ft. 2,400 ft.	8 Million Cubic Feet Gas. 1,000 Barrels Oil.
5.	Meyers	Secs. 36, T-27-N, R-8-E. Secs. 31, T-27-N, R-9-E. Secs. 1, 12, T-26-N, R-8-E. Secs. 6, 7, T-26-N, R-9-E.	Gas Sand Gas Sand Mississippi Lime	540 ft. 1,200 ft. 2,250 ft.	5 Million Cubic Feet Gas. 5 Million Cubic Feet Gas. 35 Barrels Oil.
6.	Pawhuska	Secs. 33, 34, 35, T-26-N, R-9-E. Secs. 2, 3, 4, 9, 10, 11, 14, 15, 16, T-25-N, R-9-E.	Bartlesville Mississippi Lime	1,700 ft. 2,000 ft.	10 Million Cubic Feet Gas. 75 Barrels Oil. 10 Million Cubic Feet Gas.
7.	Pershing	Sec. 1, T-24-N, R-10-E. Secs. 25, 26, 35, 36, T-25-N, R-9-E. Sec. 31, T-25-N, R-10-E. Secs. 4, 5, 6, 7, 8, T-24-N, R-10-E.	Bartlesville	2,050 ft.	750 Barrels Oil. Few Small Gas Wells.
8.	Buck Creek	Secs. 13, 14, 15, 22, 23, 24, 25, 26, 27, 34, 35, 36, T-27-N, R-10-E. Secs. 1, 2, 3, T-26-N, R-10-E. Secs. 18, 19, 20, 21, 28, 29, 30, 31, 33, 34, 35, T-27-N, R-11-E.	Peru Big Lime Bartlesville Squirrel Mississippi Lime	1,200 ft. 1,375 ft. 1,850 ft. 1,515 ft. 1,975 ft.	50 Barrels Oil. 100 Barrels Oil. 5 Million Cubic Feet Gas. 50 Barrels Oil. 5 Million Cubic Feet Gas.
9.	Okeska	Secs. 4, 8, 9, 10, 15, 16, 17, 20, 21, 22, 27, 28, 29, T-26-N, R-11-E.	Bartlesville Mississippi Lime	1,700 ft. 1,850 ft.	30 Barrels Oil. 6 Million Cuic Feet Gas.
10.	Bartlesville	T-26-N, R-12-E. Secs. 21, 28, 29, 30, 31, 32, 33, T-27-N, R-12-E. Secs. 1, 12, 13, 24, 25, 36, T-26-N, R-11-E. Secs. 4, 5, 6, 8, T-25-N, R-12-E.	Whiting Oswego Bartlesville	850 ft. 1,250 ft. 1,600 ft.	25 Barrels Oil. 30 Barrels Oil. 75 Barrels Oil.

NO FIELD—	LOCATION.	PRODUCING SANDS AND APPROXIMATE DEPTHS.		APPROXIMATE INITIAL PRODUCTION
11 South B'ville	Secs. 2, 10, 11, 12, 22, 23, 26, 27, T-25-N, R-11-E.	Bartlesville Burgess Mississippi Lime	1,700 ft. 1,775 ft. 1,800 ft.	60 Barrels Oil. 2 Million Cubic Feet Gas. 4 Million Cubic Feet Gas. 3 Million Cubic Feet Gas.
12. Ochelata Ramona	Secs. 8, 9, 16, 17, 20, 21, 28, 29, 33, T-25-N, R-12-E.	Oswego Squirrel Bartlesville	1,150 ft. 1,275 ft. 1,600 ft.	3 Million Cubic Feet Gas. 7½ Million Cubic Feet Gas. 200 Barrels Oil.
13. Avant	Secs. 12, 13, 14, 23, 24, 25, 26, 35, 36, T-24-N, R-11-E. Secs. 7, 8, 17, 18, 19, 20, 28, 30, 31, 32, T-24-N,R-12-E. Secs. 1, 2, 12, 13, 14, 23, 24, 25, 26, T-23-N, R-11-E. Secs. 5, 6, 17, 18, 19, 20, 30, T-23-N, R-12-E.	Bartlesville Mississippi Lime	1,700 ft. 1,900 ft.	75 Barrels Oil.
14. Bigheart	Secs. 7, 8, 9, 10, 15, 16, 17, 18, 19, 20, 21, 22, 27, 28, 29, 30, 31, 32, 33, T-24-N, R-11-E.	Bartlesville	1,650 ft.	75 Barrels Oil.
15. West Bigheart	Secs. 1, 2, 11, 12, 13, 14, 15, 22, 23, 26, 27, T-24-N, R-10-E.	Bartlesville	1,800 ft.	75 Barrels Oil.
16. Wynona	Secs. 11, 12, 13, 14, 23, 24, 25, T-24-N, R-9-E. Sec. 30, T-24-N, R-10-E-.	Peru (Cleveland) Bartlesville Burgess (?)	1,320 ft. 2,050 ft. 2,150 ft.	30 Barrels Oil. 6,000 Barrels Oil. 10 Million Cubic Feet Gas. 100 Barrels Oil.
17. Little Hominy	Secs. 25, 26, 35, 36, T-24-N, R-8-E. Sec. 1, 2, T-23-N, R-8-E.	Brunner Peru Oswego-Wheeler Deeb	475 ft. 1,600 ft. 1,750 ft. 2,100 ft.	75 Barrels Oil. 50 Barrels Oil. 75 Barrels Oil. 5 Million Cubic Feet Gas.
18. Hominy	Secs. 8, 9, 10, 15, 16, 17, T-23-N, R-8-E.	Sand Mississippi Lime	600 ft. 2,275 ft.	10 Barrels Oil. 500 Barrels Oil.
19. Hominy Townsite (Section 8)	Secs. 25, 36, T-23-N, R-8-E. Secs. 30, 31, T-23-N, R-9-E. Sec. 1, T-22-N, R-8-E.	Wheeler-Oswego Bartlesville	1,750 ft. 2,150 ft.	750 Barrels Oil. 400 Barrels Oil.
20. Osage City	Secs. 1, 2, 11, 12, 13, 14, 23, 24, T-21-N, R-8-E. Secs. 7, 18, 19, 20, 29, 30, T-21-N, R-9-E.	Layton Cleveland Bartlesville	1,125 ft. 1,650 ft. 2,350 ft.	25 Barrels Oil. 25 Barrels Oil. 250 Barrels Oil.
21. Boston	Sec. 31, T-22-N, R-8-E. Sec. 6, T-21-N, R-8-E. Secs. 25, 36, T-22-N, R-7-E. Secs. 1, 12, T-21-N, R-7-E.	Peru Bartlesville	2,175 ft. 2,275 ft.	8 Million Cubic Feet Gas. 75 Barrels Oil.

NO	FIELD—	LOCATION	PRODUCING SANDS AND APPROXIMATE DEPTHS.		APPROXIMATE INITIAL PRODUCTION
22.	Section 36	Secs. 35, 36, T-22-N, R-9-E. Secs. 1, 2, T-21-N, R-9-E.	Cleveland	1,475 ft.	20 Barrels Oil.
23.	Wildhorse Creek	Secs. 28, 32, 33, T-22-N, R-10-E. Secs. 4, 5, 6, 8, 9, 16, 17, T-21-N, R-10-E.	Cleveland Bartlesville	1,200 ft. 1,900 ft.	75 Barrels Oil. 75 Barrels Oil.
24.	Turkey Creek	Secs. 1, 2, 11, 12, 13, 14, 15, 22, 23, 24 25, 26, 27, 34, 35, 36, T-22-N, R-10-E.	Cleveland Bartlesville	1,175 ft. 1,675 ft.	25 Barrels Oil. 75 Barrels Oil.
25.	Bull Creek	Secs. 19, 20, 29, 30, 31, 32, T-23-N, R-11-E. Secs. 5, 6, 7, 8, T-22-N, R-11-E.	Cleveland Bartlesville	925 ft. 1,725 ft.	30 Barrels Oil. 60 Barrels Oil.
26.	North Skiatook	Secs. 5, 8, T-22-N, R-12-E.	Burgess	1,800 ft.	100 Barrels Oil.
27.	Skiatook	Secs. 27, 33, 34, T-22-N, R-12-E. Secs. 3, 4, 10, 15, T-21-N, R-12-E.	Bartlesville Mississippi Lime	1,475 ft. 1,200 ft.	100 Barrels Oil. 50 Barrels Oil.
28.	Delaware	Secs. 19, 20, 29, 30, T-21-N, R-12-E.	Burgess Wilcox	1,600 ft. 2,000 ft.	5 Million Cubic Feet Gas. 150 Barrels Oil. 5 Million Cubic Feet Gas.
29.	Flatrock	Secs. 31, 32, 33, T-21-N, R-12-E. Secs. 3, 4, 5, 6, 7, 8, 9, 10, 15, 16, 17, 20, 21, 22, 27, 28, T-20-N, R-12-E.	Bartlesville	1,400 ft.	75 Barrels Oil.
30.	Cleveland	Secs. 20, 21, 25, 26, 27, 28, 29, 33, 34, 35, 36, T-21-N, R-8-E. Secs. 1, 2, 3, 11, 12, 13, T-20-N, R-8-E. Sec. 31, T-21-N, R-9-E. Secs. 5, 6, 7, 8, 17, 18, T-20-N, R-9-E.	Layton Cleveland Skinner Bartlesville Tucker	1,200 ft. 1,700 ft. 2,200 ft. 2,400 ft. 2,600 ft.	20 Barrels Oil. 20 Barrels Oil. 10 Million Cubic Feet Gas. 75 Barrels Oil. 15 Million Cubic Feet Gas. 60 Barrels Oil. 500 Barrels Oil.
31.	Hallett	Secs. 1, 12, 13, T-20-N, R-8-E. Secs. 6, 7, 8, 17, 18, T-20-N, R-8-E.	Cleveland Skinner Tucker	1,800 ft. 2,300 ft. 2,700 ft.	15-25 Barrels Oil. 1½ Million Cubic Feet Gas. 100-200 Barrels Oil.
32.	Jennings.	Secs. 20, 21, 28, 29, T-20-N, R-7-E.	Tucker	2,600 ft.	150-200 Barrels Oil.

CUSHING DISTRICT.

The Cushing district includes parts of Creek and Payne counties and includes the Cushing, West Cushing, Yale, Ripley and Ingalls pools. For convenience the small gas pool near Otoe in western Pawnee county is included in this district. The accompanying sketch map (fig. 79) shows the producing areas in the Cushing and Yale pools.

Cushing Pool.

The Cushing pool has been of the utmost importance in point of amount of production and affect upon the market. While it is already past its maximum its production is still of considerable importance and its great historic interest makes it worthy of somewhat more detailed notice than is given to the majority of the pools in Oklahoma.

The pool has been treated rather fully in two publications.

(1) The Cushing Oil and Gas Field, Oklahoma, by Frank Buttram, published as Bulletin No. 18 of the Oklahoma Geological Survey in 1914.

(2) Geologic Structure in the Cushing Oil and Gas Field, Oklahoma, and its relation to the oil, gas and water, published as Bulletin No. 658 of the United States Geological Survey in 1917.

In the following pages both reports are used extensively.

Location and area—The Cushing pool is located in the extreme western part of Creek county, with some production from Payne county to the west. The greater part of the development is in the western half of Tps. 17 and 18 North, Range 7 East. The name is taken from the town of Cushing, about 12 miles west of the field.

History and development—The discovery well was drilled by C. B. Shaffer on the Wheeler lease, sec. 31, T. 18 N., R. 7 E., in March, 1912. Development was rapid but the production was all from the Wheeler and Layton sands. In spite of the discovery of an important northern extension in the summer of 1913, the field began to show signs of exhaustion, when, in December, 1913, the Prairie Oil and Gas Company drilled to the Bartlesville sand in sec. 3, T. 17 N., R. 7 E., and secured a 500 barrel well. This was the beginning of the most feverish activity and of the development of one of the phenomenal pools in the history of the petroleum industry.

The most recent development has been the securing of good production from the Tucker sand, below the Bartlesville. The first well in the Tucker sand was the largest so far drilled in the state,

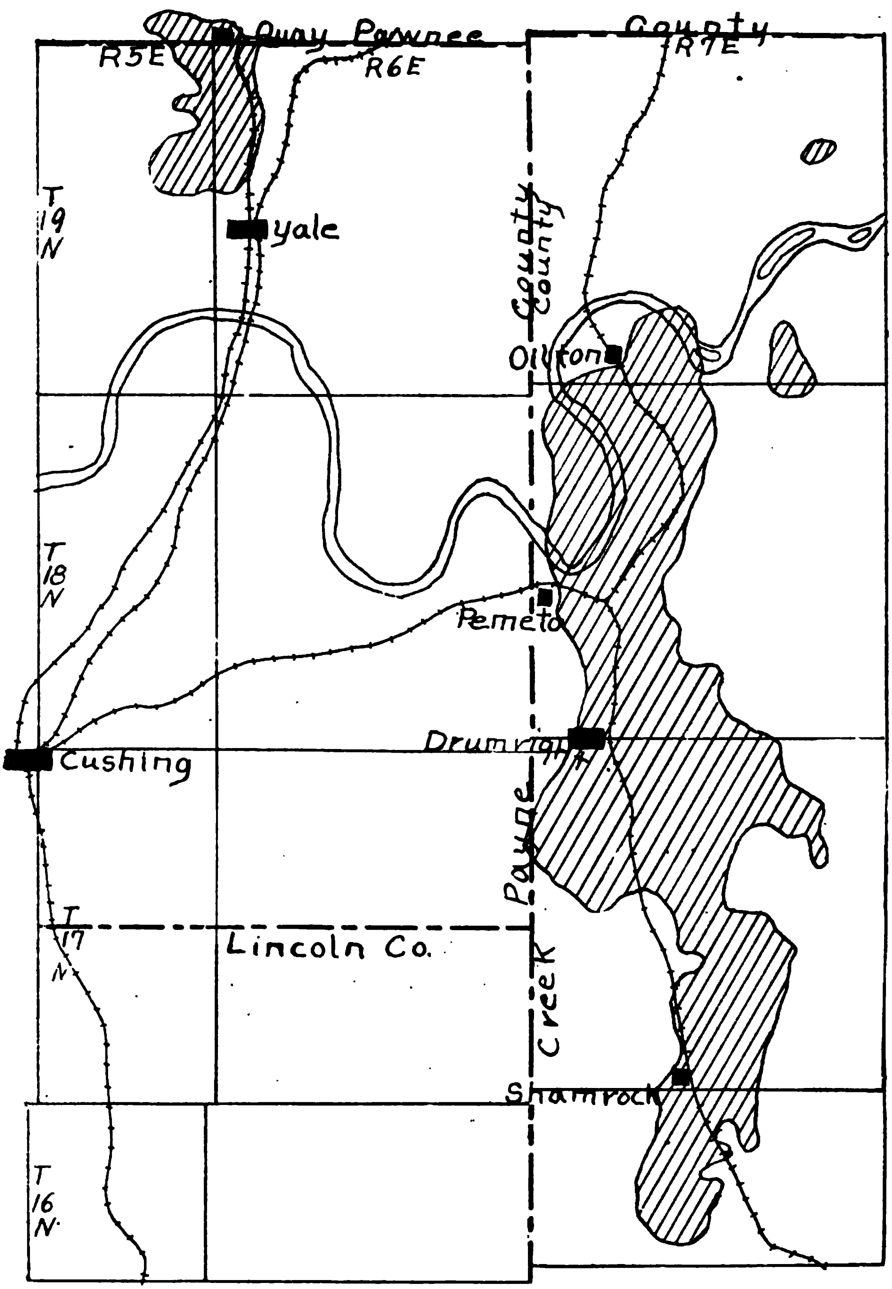

Fig. 79.—Map showing producing areas in Cushing district.

with an initial production of over 15,000 barrels per day. The productive area in the Tucker sand, however, was small and the wells declined rapidly.

Stratigraphy—The rocks of the area all belong to the Pennsylvanian system. The most prominent bed outcropping in the field is known as the Pawhuska limestone, which is about five feet thick in the southern part of the field, thickening to the north, where it is composed of three limestone members separated by shale. About 150 feet of alternating sandstones and shales are exposed in the field below the Pawhuska limestone and above a heavy sandstone, thought to be the Elgin sandstone.

Little is known of the stratigraphy for 1,000 feet or more below the Elgin sandstone, except what can be determined from the study of the well records. The formations outcrop in the Hominy quadrangle to the east of the field. This quadrangle has been mapped by the United States Geological Survey, but the results have not been published.

The formations at greater depths are the southward extensions of the formations outcropping in the northeastern oil fields. Owing to the disappearance of the limestones to the south and west, and the thickening of the sands and shales it is almost impossible to make detailed correlations with the well records of the Cushing pool. It is thought, however, that the Wheeler sand is the Fort Scott (Oswego) limestone of the northeastern fields.

Structure—The Cushing field is located in the general area of northwest dip—the Prairie Plains monocline. However, the structure of the immediate field is a major anticline folded into a rather complex system of domes and synclines.

The principal producing areas are domes, which are described by Buttram as follows:

The *Dropright dome* is so named from the town of Dropright which has sprung up as a result of remarkable activity on the slope of the dome. This anticline extends from Cimarron river in sec. 34, T. 19 N., R. 7 E., west of southwest to E. ½ sec. 17, T. 18 N., R. 7 E., where the dome reaches its maximum development. From this point southward to the southeast corner of sec. 20 it dies out rapidly.

The elongated dome thus described is about 5 miles in length and the apex or summit is well toward the south end. From the summit northward for a distance of about 2 miles the northward dip is very gentle. The slope is very gentle, but from the middle of sec. 4 northward to Cimarron river the dip is more rapid.

The dip on the west slope also is gentle for about a mile beyond the Cimarron river. However, from this point on to the westward the dip is very steep and reaches a maximum of about

170 feet to the mile, this being the maximum dip in the field so far as is known to the writer. The east side of the dome, too, shows a gentle slope at first. The steepest dip is about the middle of sec. 16. In cross section therefore this dome shows a short eastern limit and a much longer, steeper, western limit. Likewise in longitudinal section the south end is short and the north is much longer.

The Drumright dome is so named from the town of Drumright, which is situated on the western slope of the dome. This structure, as above noted, might be regarded as the continuation of the Dropright dome, the two making an anticline, but it is best described separately. It is by no means so well developed as the preceding structure. The axis rises from the southeast corner of sec. 20, T. 18 N., R. 7 E., to about the middle of the W. ½ of sec. 10, T. 17 N. Both the north and south dips are very gentle, as compared with those of the Dropright dome. The total dip on the north end of the dome is not much in excess of 50 feet, while the south dip is between 30 and 40 feet. The west slope is comparatively gentle, being about 75 feet to the mile. This slope as shown by the structural contours is much more irregular than the corresponding slope of the Dropright dome. The east slope of this dome is somewhat more than a mile in length, and very gentle, the dip being about 50 feet to the mile. As compared with the other east dips in northeastern Oklahoma, however, this is rather pronounced. It was on the west slope of this dome in sec. 32, T. 18 N., R. 7 E., that the discovery well was completed in March, 1912.

The southernmost of the three principal domes is termed the Shamrock dome from the Post Office by that name situated some 2 miles to the southwest of the apex of the dome. This dome is seen to be closely related to the Drumright dome. The axis rises from about the middle of the west side of sec. 10, south to the center of sec. 22, thence dropping to the southwest. The southern limit of the dome is beyond the confines of the map, the axis passing out of T. 17 N., in the southeast corner of sec. 33.

The west slope of this dome is long and gradual, being a part of the regular moniclinal structure of the region. The east slope of the dome was not accurately mapped on account of lack of good exposures of formations, and also through want of well logs. It is certain, however, that the east dip continues from the apex of the dome in sec. 22 approximately to Little Deep Fork Creek in the east ½ of sec. 23. This makes one of the best developed domes of the entire area, being surpassed in magnitude only by the Dropright dome.

It will be noted in passing that as this is being written (1914) wells of large production are being brought in in the Bartlesville sand on this dome, the well of the Numa Oil company on the Fife lease

in sec. 22, starting off at a reported production approaching 8,000 barrels per day. It is safe to say that the area involved in this dome will be one of the most productive parts of the entire field.

The Mount Pleasant dome takes its name from Mount Pleasant church, which is situated on the north slope of the dome. This is one of the few structures that is characterized by east-west elongation. The dome extends from the west ½ sec. 10 eastward and somewhat northward through sec. 11 into the northwest part of sec. 12, T. 17 N., R. 7 E. It thus has a length of not to exceed 2 miles. Transversely it may be said to extend from about the center of sec. 14, northward to the center of Sec. 2, a distance of about 2 miles. The east dip of the dome, which from an economic standpoint is the most important, approximates 65 feet. The great production at the present (1914) being obtained from the Bartlesville sand is from the region where this dome comes into contact with the south end of the Drumright and the north end of the Shamrock domes.

* * * * * * * * * * * *

In general the production in the Cushing field follows the structure very closely as is pointed out in the quotation just given.

Producing horizons—Commercial production has been obtained from four different horizons, the Layton, Wheeler, Bartlesville, and Tucker sands. In addition to these the Jones and Cleveland sands have shown some oil and gas but not in sufficient quantity to be of importance.

The name Layton was first applied to a sand found productive on the Layton farm in the Cleveland field and the sand in the Cushing field is supposed to be at the same horizon. It is generally a fairly soft, porous, coarse-grained sandstone, with an average thickness of about 30 feet although the thickness as reported in logs varies from a very few feet to 100 feet or even more. The top of the Layton sand is found at an average depth of 1,530 feet below the top of the Pawhuska limestone, (1,400-1,500 feet below the surface) and 810 feet above the top of the Wheeler sand (Fort Scott or Oswego limestone.) The formations between the Layton and Wheeler sands thicken to the west so that the interval between the sands increases in that direction.

The Wheeler sand received its name from the farm on which the first producing well of this horizon was obtained. It is really a formation consisting of two members of coarse-grained, light-brown limestone with a shale break, believed to be the Fort Scott (Oswego) limestone. The average thickness of 75 feet. The top of the sand lies from 700 to 810 feet below the top of the Layton sand (2,200-2,300 feet below the surface) and 390-400 feet above the top of the Bartlesville sand.

The Bartlesville sand is supposed to be a continuation of the principal producing sand in the district from which it takes its name. In the Cushing pool it is probably about 100 feet thick and is a soft, porous, coarse-grained, brown sand-stone. The top of the Bartlesville lies at an average distance of 420 feet below the top of the Wheeler (2,600-3,000 feet below the surface.)

The production from the Tucker sand is more recent and covered much less area than that of the other sands. In the Bartlesville region, in Washington county, the sand is principally a gas producer, is 150-200 feet below the top of the Bartlesville sand and is about 20 feet thick. Even if it continues with the sand in the Bartlesville region, it may be very different in character and thickness in a locality so far distant as the Cushing field.

Production—The Cushing pool has been marked by wells of very large production. In the Layton and Wheeler sands wells of 1,000 barrels were not uncommon and the average initial production for 1912 was 227.4 barrels per day. The Bartlesville sand wells were very much larger, most of them in the early development having an initial production of more than 1,000 barrels, and many of them of more than 5,000 barrels. The average initial production of nearly 700 wells was practically 1,000 barrels per day.

As is usually the case with wells of unusually large production, the decline was very rapid. *Buttram cites instances showing the rapid decline. One hundred sixty-one Layton and Wheeler wells had an average daily production of 23,079 barrels in February, 1913, while at the end of May, 301 wells were giving an average daily production of 18,574 barrels, indicating a decline of one-half in the 161 wells in three months. The rate of decline in the Bartlesville sand wells is even more rapid. This is shown by the decline in the production of the pool from 300,000 barrels per day in April to an average of less than 100,000 per day in December, 1915, in spite of the new wells which were being brought in continually.

Character of oils—The Cushing oil pool furnishes the highest grade of crude so far found in any important pool west of the Alleghenies. The Layton crude averages about 41 degrees, the Bartlesville about 40 to 41 degrees and the Wheeler 38 to 39 degrees Baume. The mixed crude gives on refining about 35 per cent gasoline and benzine, 20 per cent kerosene, 30 per cent distillate, 15 per cent residium and 5 per cent loss.

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*Op. cit. pp. 50-31.

Statistics of production:

TABLE OF PRODUCTION OF CUSHING FIELD BY MONTHS, 1914-1916.

Month	1914	1915	1916
January	652,076	7,797,532	2,664,713
February	751,637	7,501,004	2,819,033
March	1,577,168	8,352,020	3,060,818
April	1,668,866	8,104,980	2,769,112
May	2,040,454	8,015,205	3,090,739
June	1,904,627	2,049,730	3,558,851
July	1,691,460	6,566,110	4,175,153
August	1,442,817	5,557,142	4,052,448
September	1,644,857	4,588,230	3,842,208
October	2,398,686	3,793,160	3,650,646
November	2,946,265	3,287,160	3,403,004
December	3,226,072	3,232,476	2,794,323
Total	21,944,985	73,844,749	39,911,048

Beal's work (referred to above) was done much more recently than that of Buttram and after the field had been well defined in all the productive sands. He makes no additions to the surface geology as determined by Buttram but points out the variations between the structure of the surface beds and that of the different producing sands. Detailed contour maps on the different sands are given. These maps also show the water surface, the areas of greatest production and the areas of oil and gas production.

The cause for the extremely rapid decline of the field is given as the great number of wells drilled and the extraordinarily rapid decrease of the gas pressure due to the waste of gas. The water from sands above and below the productive sands also invaded the productive sands due to poor casing and improper plugging of abandoned wells and has been a contributing factor to the decline of the field.

Yale pool—This pool is located on a pronounced anticlinal structure. It was opened in 1914 by a well in sec. 7, T. 19 N., R. 6 E., and development has continued steadily until the present, and about 4 square miles lying along the line between Rs. 5 and 6 E., in T. 19 N., between Yale and Quay are productive.

There are four productive sands at average depths of about 2,720, 2,875, 3,050, and 3,130 feet respectively. The two upper sands have produced only gas in most of the territory. Capacities of as high as 20,000,000 cubic feet per day have been reported from the second sand

The wells are of only moderate size, very few having an initial production as high as 1,000 barrels. The production holds up well, however, and the field is a paying one. On account of the depth and the comparatively small wells, the field has not produced any great excitement and the development has proceeded in an orderly manner.

West Cushing pool—The West Cushing pool is located east of Cushing in the eastern part of T. 18 N., R. 5 E., where there are

two anticlinal folds separated by a syncline. Both folds have been fairly well tested but only gas wells have resulted. Some of the wells have had capacities of from 10,000,000 to 20,000,000 cubic feet per day.

Ripley and Ingalls pools—Well defined structure 3 miles west of Ripley and at Ingalls, in T. 18 N., R. 5 E., have been well tested but have produced only gas and a few small oil wells. Most of the activity in these pools was in 1914, 1915 and 1916. They have been rather quiet for the past year or two.

Early in 1919 it was reported that a strong flow of gas had been encountered at a depth of about 700 feet in sec. 15, T. 16 N. R. 5 E. This well is in rather promising territory on a faulted anticline. A structure near Otoe has given several gas wells of large capacity but no oil production of importance. The pool was opened late in 1915.

KAY COUNTY DISTRICT.

(By F. L. AURIN)

General Statement.

Kay county is one of the northern tier of counties in Oklahoma bordering Kansas. The geologic formations are for the most part the non-red Permian. The following formations are exposed in this county: Matfield shale, Fort Riley limestone, Doyle shale, Winfield limestone, Uncas shale, Herington limestone, and an unclassified series of thin limestones and shales. The general structure is a monocline having a dip of about 30 feet per mile to the west. The following oil and gas pools have been discovered and developed: Newkirk, Ponca City and Blackwell. In the Kay county district are included also the Billings, Garber and Barnes pools. The producing areas of the Newkirk, Ponca City and Blackwell pools are shown in fig. 80, and of the Garber, Billings and Barnes pools in fig. 81.

Producing Areas.

Newkirk pool—The Newkirk pool is almost exclusively limited to secs. 35, T. 28 N., R. 3 E., and secs. 2, 10, 11 and 15, T. 27 N., R. 3 E., and near the town of Newkirk.

The first wells drilled in this field were near Newkirk in 1905. They were small, shallow gas wells and varied in depth from 600 to 2,200 feet. A short time after the discovery they became exhausted or were ruined by salt water. It was not until the latter part of 1913 that the first oil well was brought in, which was near the center of sec. 2, T. 27 N., R. 3 E. During 1914 the production from increased development amounted to more than 2,500 barrels per day about the middle of the year. This production came from

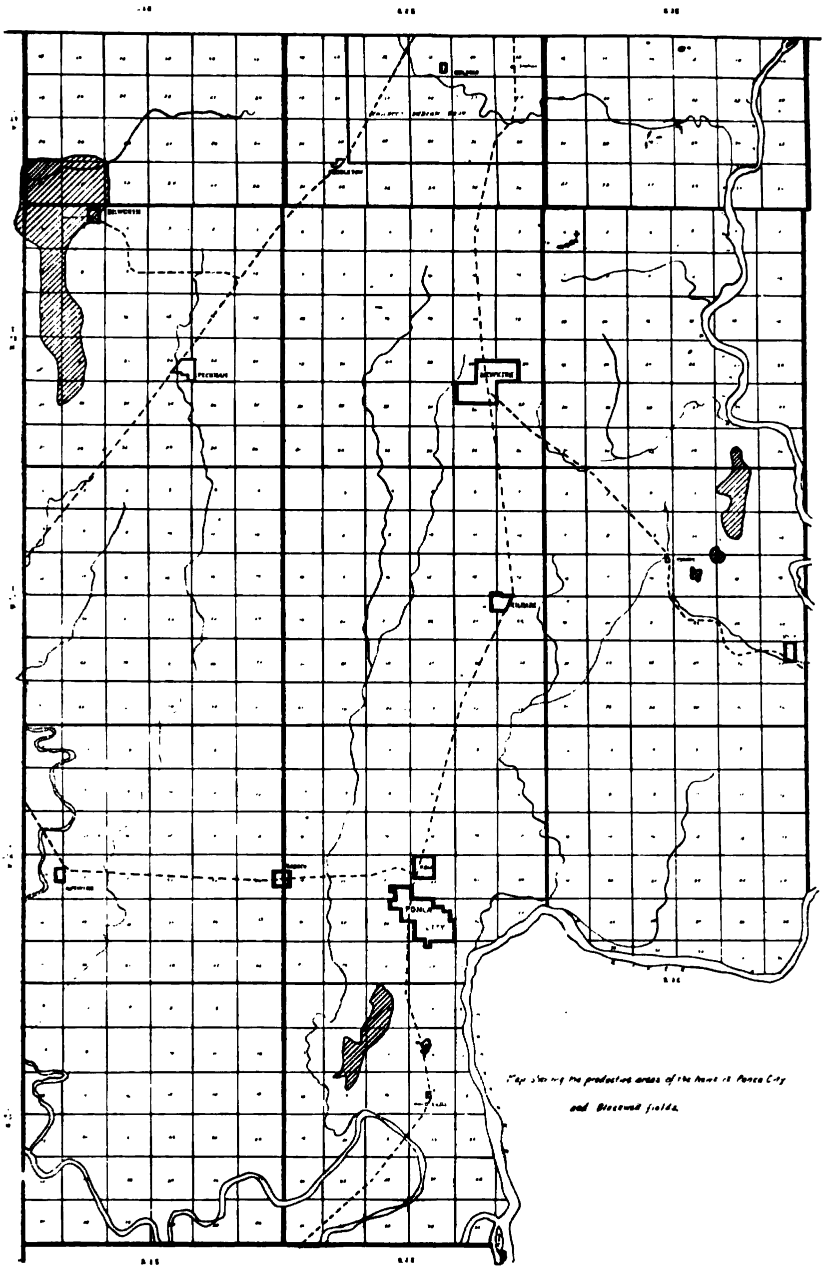

Fig. 80.—Map showing producing areas of the Newkirk, Ponca City and Barnes pools.

the 900-foot sand. The largest initial production was reported at 500 barrels, and the average about 200 barrels. The productive area was gradually extended. In 1915 and 1916, there were no special features of development, but in 1917 considerable excitement was created by the discovery of a deep sand on the Biggerstaff farm in sec. 10, T. 27 N., R. 3 E. Production was found at a depth of 3,223 feet. During this year and 1918 a number of wells were drilled to the deep horizon in the vicinity of this well and also in secs. 15, 22, 27, 33 and 34, T. 27 N., R. 3 E. The initial production of the wells ranged from a few garrels to 2,300 barrels.

Production was found in a well in sec. 34 of the same township in a sand at a depth of about 3,355 feet. Most of the development in the early part of 1919 has been in sec. 15, T. 27 N., R. 3 E. However, the results have been so discouraging that only a few wells are drilling to the deeper sands. The present daily production (March, 1919) of the field is about 3,500 barrels from about 50 producing wells. There are 3 pipe lines taking the production from this field.

The wells in this field start at the Fort Riley limestone. There are 3 producing sands. The 900-foot which has been the most important producing horizon has an average thickness of about 15 feet. It has been correlated with the Elgin sandstone by some geologists. The wells in this sand are steady producers. A few wells have found some production in a 1,400-foot sand. The deep sand is encountered at an average depth of 3,150 feet. The production is very erratic and "spotted." The thickness of this sand is reported as high as 100 feet. In several well the productive sand is reported at 3,350 feet. This deep production may be in the Mississippi lime.

The oil from the 900-foot and deep sands is approximately the same, being green in color and ranging in gravity from 38 degrees to 41.5 degrees Baume.

Ponca City pool—The Ponca City pool including what is known as the South Ponca pool and a few producing wells northeast of Ponca City is limited to all or a part of the following: secs. 8, 9, 18 and 19, T. 26 N., R. 3 E., Secs. 11, 12, 13, 14 and 24, T. 26 N., R. 2 E., and secs. 4, 8, 9 and 17, T. 25 N., R. 2 E. The main Ponca City field is in T. 25 N., R. 2 E.

The first well in this field was drilled in 1905 by a local company. Gas was encountered at a depth of 500 feet. In 1906, 1907 and 1908 the development of the shallow sand was centered around sec. 34, T. 26 N., R. 2 E. The total volume of gas sold during this time was about 178,000,000 cubic feet. The first important oil well was brought in during June, 1911, on the Willie Cry farm in sec. 8, T. 25 N., R. 2 E. Development proceeded very rapidly. In 1912 there were over 30 wells producing with an average daily

production of 34 barrels. The total production for 1913 amounted to 722,358 barrels. During 1914, 1915, 1916, 1917 and 1918 development gradually decreased. In January, 1919, the Marland Refining Company completed a well on the Miller farm in sec. 9, T. 25 N., R. 2 E., having an initial production of 1,000 barrels from a sand at a depth of 3,929 feet. The daily production (March 1, 1919) was about 1,100 barrels.

The surface horizon in this field is usually the Herington limestone. The first sand of any importance occurs 375 feet below the Herington and the average thickness is about 17 feet. This sand has also produced gas in paying quantities.

The most important gas sand is the 500-foot which has an average thickness of about 37 feet. The early wells were drilled to this horizon. The initial volumes ranged from a few thousand to 7,000,000 cubic feet. Some geologists correlate this sand with the gas sand at Dexter, Arkansas City and several other places in Kansas.

The 1,000-foot sand, productive of both oil and gas, has an average thickness of about 35 feet.

The 1,330-foot sand, also productive of oil and gas, ranges in thickness from 15 to 40 feet.

The most productive oil sand which also yields some gas is the 1,550-foot or Ponca sand. The average thickness is about 18 feet. The initial production of wells in this sand has been as high as 10 barrels an hour.

The 2,100-foot sand has been found to be productive of both oil and gas.

There are two deep sands, one of which was productive in Willie Cry, No. 9, sec. 8, T. 25 N., R. 2 E., at a depth of 3,743 feet, the other in Mollie Miller No. 9, sec. 9, T. 25 N., R. 2 E. at a depth of 3,929 feet. The former had an initial production of 20 barrels and the latter 1,000 barrels.

The oil from the 1,550 and 2,100-foot sands is olive green in color and the gravity ranges from 40 degrees to 41 degrees Baume, while that from the 3,743 and 3,929 foot sands has a reddish-green color and a gravity of about 41 degrees Baume.

Blackwell pool—The Blackwell pool is located in Kay county and covers approximately all or a part of the following: secs. 31, 32, T. 29 N., R. 1 E., secs. 5, 6, 7, 8, 17, 18, 19, 20, 29 and 30, T. 28 N., R. 1 E., and also the shallow gas producing area in secs. 12, 13, 24, 25, 26, 35, 36, T. 28 N., R. 1 W., and secs. 2, 10, 15, 17, and 21, T. 27 N., R. 1 W.

Previous to 1912 only shallow gas wells had been drilled in this field. This early development extended from near Blackwell northward for a distance of about 10 miles. The initial volumes of the gas wells ranged from a few thousand to 5,000,000 cubic feet. About

37 wells were drilled in 1912 and 21 of these produced gas. In 1914 the first oil well of any importance was drilled in the Swenson farm in sec. 32, T. 29 N., R. 1 E. The initial production was estimated at 600 barrels from a sand at a depth of 3,360 feet. Gas wells having an initial volume from 250,000 to 65,000,000 cubic feet were also completed at this time. The field was slowly developed on account of the length of time and trouble in drilling to the Swenson or deep sand. In practically all of these deep wells, heavy volumes of gas were encountered in the shallow sands. The volumes of gas, although of commercial value, were not utilized as a rule, but were mudded off and drilling continued to the deep oil-producing sand.

By January 1, 1916, most of the development was centered around sec. 32, T. 29 N., R. 1 E., and later was extended into the adjoining sections. During this year wells having an initial production as high as 3,500 barrels, were completed in sec. 32, T. 29 N., R. 1 E., and sec. 6, T. 28 N., R. 1 E. A well estimated to have had an initial production of 500 barrels was completed on the Curry farm in sec. 18, T. 28 N., R. 1 E., in the 1,900-foot sand. During 1917 and 1918 the principal development was the extension of the shallow sand production into secs. 17, 18, 19, 20, 29, and 31, T. 28 N., R. 1 E. In the early part of 1919 most of the development in the shallow sand areas was in secs. 20 and 29 of the above township.

In some of the deep wells in this pool more than 12 sands, productive of oil or gas in various quantities, have been reported, but there are about 10 sands, some of which are sandy limestones, found throughout the field where wells have been drilled to 3,400 feet. There are several gas sands above the 700-foot sand, but they are not of sufficient importance to be considered here. The 700-foot gas sand is usually found throughout the field. Initial capacities as high as 10,000,000 cubic feet have been reported. The 900-foot and 1,400-foot gas sands have been found in the northern part of the field or wherever wells have been drilled to these depths. The initial capacities vary from showings to a few million cubic feet. The 1,400-foot gas sand had an initial volume of as high as 5,000,000 cubic feet in the NW. ¼ sec. 20, T. 28 N., R. 1 E. The 1,600-foot and 1,700-foot sands are productive of oil and gas. The former has produced as high as 2,000,000 cubic feet of gas in initial volume and the latter as high as 10 times this amount. These sands show gas in the northern part of the field, but in secs. 17 and 18, T. 28 N., R. 1 E., and southward, they produce as high as 1,200 barrels of oil on initial production, the average being about 200 barrels. The 1,900-foot sand shows gas in some quantities throughout most of the field and in secs. 8, 17, 18 and 20, T. 28 N., R. 1 E., is productive of oil. The 2,000-foot sand produces oil in sec. 18, T. 28 N., R. 1 E., and sec. 31, T. 29 N., R. 1 E. An initial production as high as

350 barrels has been reported. The 2,200-foot, 2,600-foot and the 3,200-foot gas sands have shown gas in varying amounts wherever wells have been drilled to these horizons. The best production in the 2,200-foot sand has been found in secs. 31 and 32, T. 29 N., R. 1 E., and secs. 5 and 6, T. 28 N., R. 1 E., where initial volumes as high as 15,000,000 have been reported. The 3,400-foot or Swenson sand is productive of oil and gas. Oil production has been found in secs. 31, 32, T. 29 N., R. 1 E., and secs. 7, 8 and 18, T. 28 N., R. 1 E. The initial production ranges from a show to as high as 3,500 barrels. Gas is usually associated with the oil in most of the wells. The Swenson No. 1 in the SW. ¼ sec. 32, T. 29 N., R. 1 E., which was drilled in 1914, and had an initial production between 400 and 600 barrels, was producing about 15 barrels, March 15, 1919.

More than 370 wells have been drilled in the Blackwell field and adjacent territory (March, 1919) of which 184 were oil wells, 138 gas wells and about 46 dry holes. The daily production March 15, 1919, was about 7,500 barrels from 170 producing wells.

Garber pool—The Garber pool is located about 14 miles east of Enid and 3 miles south of Garber. The productive area which is about 5 square miles, covers all or a part of the following: secs. 1, 12, 13, 14, 24 and 25, T. 22 N., R. 4 W., and secs. 7, 18, 19 and 30, T. 22 N., R. 3 W.

The first well drilled in this pool was in the latter part of

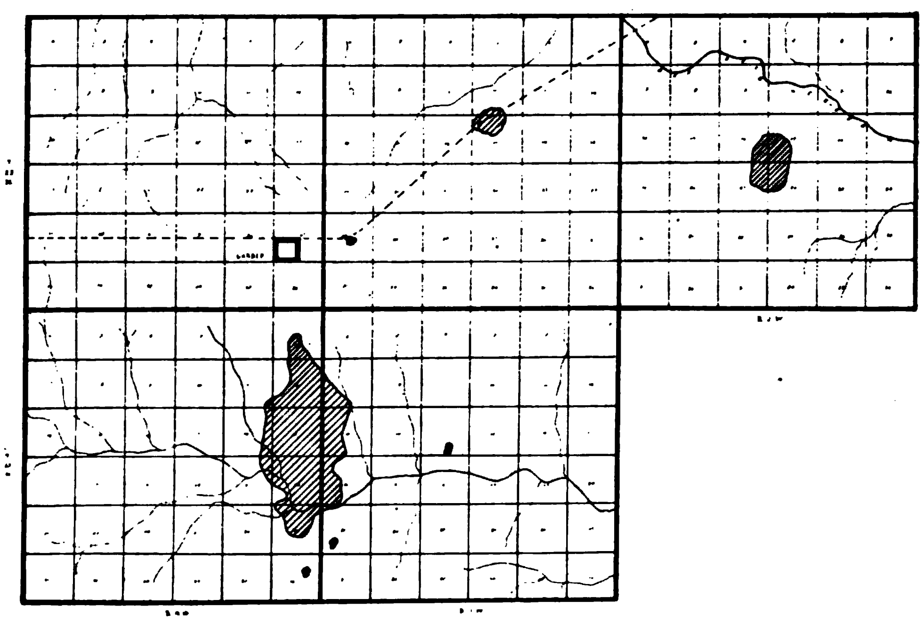

Fig. 81.—Map showing producing areas in the Garber, Billings and Barnes pool.

1916 on the Hoy farm in sec. 25, T. 22 N., R. 4 W. This location was a considerable distance from production and was made on geological advice. The discovery well had on its initial production of 150 barrels of oil which tested about 45 degrees Baume. During the early part of 1917 there was considerable drilling to the 1,100-foot or Hoy sand. Most of the wells did not go below this horizon. The field was extended in all directions from the discovery well but more especially to the northward. In July, 1917, a deeper sand was discovered on the Hotson farm in the NW. 1/4 sec. 25, T. 22 N., R. 4 W. By August the field had been extended to the northern boundary of sec. 13 of the same township. During 1918 some of the wells which did not find paying quantities of oil in Hoy sand were drilled deeper with the result that something like 7 producing sands were found between 1,100 and 2,200 feet. After these discoveries very few wells were abandoned at a shallow depth. If no production was found in the shallow sand they would as a rule, find production in some sand below it.

The most important feature of development in the latter part of 1918 and the early part of 1919 was the drilling of so-called twin and triplet wells. As high as 4 wells have been drilled in a bunch within a square of 100 to 200 feet. All of these wells would be producing from different sands. In addition to this, production was found in the SE. cor. sec. 11, T. 22 N., R. 4 W., from a sand at a depth of 2,100 feet; in the SE. part of sec. 14 (same township) at about 2,225 feet in the SW. cor. SE. 1/4 sec. 12 (same township) at 1,630 feet; and in the W. 1/2 SW. 1/4 sec. 7, T. 22 N., R. 3 W., in sands from 1,300 to 2,245 feet.

The surface horizon at which the wells start is the Permian Redbeds. There are so many sands in this field that no attempt will be made to describe all of them. Some of them are lenticular and are not found throughout the field. The Hoy sand is found in practically all wells drilled. It is found at an average depth of 1,100 feet and has an average thickness of about 20 feet. The average initial production is about 75 barrels and the highest about 900 barrels. The 1,300-foot sand in the SW. 1/4 SW. 1/4, sec. 7, T. 22 N., R. 3 W., is very productive, ranging in initial production from 75 to 800 barrels per day. Production is found in some wells at about this horizon in sec. 24, T. 22 N., R. 4 W. The Hotson sand is encountered at about 1,450 to 1,525 feet and is productive in secs. 18 and 19, T. 22 N., R. 3 W., and secs. 23, 24, 25, T. 22 N., R. 4 W. The initial production ranges from a few to as high as 600 barrels, the average being about 100 barrels. The thickness averages about 25 feet. A sand found at about 1,740 feet near the center of sec. 24, T 22 N., R. 4 W., produces from 25 to 300 barrels initial production in certain wells. Other sands encountered at the following depths are

productive in various parts of the field: 1,250, 1,650, 1,800, 1,900, 2,100, 2,225 and 2,300 feet.

In the SW. 1/4 SW. 1/4 sec. 16, T. 22 N., R. 3 W., several wells have been completed with an initial production of from 5 to 15 barrels from a sand at a depth of 1,525 feet. These wells are about 2 miles east of the Garber field.

About 202 wells have been drilled in the Garber field. Of this number 182 are oil wells, 10 dry holes and 10 gas wells. The total daily production of the field March 15, 1919, was about 7,000 barrels.

The oil in the Garber field ranges from 41.5 degrees to 45 degrees Baume. As a rule the gravity is about the same for all sands. The color of the oil is light green.

Billings pool—The Billings pool is located about 6 miles southwest of the town of Billings, Noble county and 12 miles northeast of the Garber field. It covers all or a part of the following: secs. 15, 16, 21 and 22, T. 23 N., R. 2 W. The productive part has an area of about 2 square miles.

The discovery well in the Billings field was drilled on geological advice and about the same time as the first well in the Garber field. It was not completed until the early part of 1917. About 5 gas sands were encountered at shallow depths and oil at 2,033 and 2,129 feet, with an initial production of 500 barrels. This field was rather slow in development. During 1917 and 1918 the field was gradually extended northward to the center of sec. 15. Dry holes have been drilled to the southeast, east, northeast and west of the productive area. In the early part of 1919 only a few wells were completed. The daily production (March 15, 1919) was estimated at 5,000 barrels.

About 72 wells have been drilled in this field. Of this number 48 were oil wells, 10 dry holes, and about 13 gas wells.

There is an interesting test being drilled in the N. E. 1/4 sec. 20, T. 24 N., R. 1 W., about 7 miles northeast of the Billings field. The present depth, March 15, 1919, is 4,485 feet. At a depth of 4,330 feet a hard sand was encountered which had a showing for about 15 barrels of high grade oil. This is the deepest oil production so far found in Oklahoma.

The surface horizon in the Billings field is the Permian Redbeds. A few thin limestone beds interstratified with shale are exposed. There are at least 7 horizons which show gas in varying amounts, some of these are sands and sandy limestones. They occur at something near the following depths: 500, 550, 680, 745, 890, 1,030, 1,155, 1,725, 1,750 and 1,925 feet. The initial volumes range from showing to 10,000,000 cubic feet. The producing sand, known as the Hoover sand, occurs at about an average depth of 2,030 feet. Gas is usually encountered just above the oil in the sand. The ini-

tial daily production varies from 50 to 2,700 barrels, the average being about 1,000 barrels.

The oil from the Hoover sand has a gravity ranging from 41.5 degrees to 44 degrees Baume, and is light green in color.

Barnes pool—The Barnes field, so named from the Barnes farm on which the discovery well was completed, is located about midway between the towns of Billings and Garber. The productive area is limited to a small area in the S. ½ S. W. ¼ sec. 10 and N. ½ NW. ¼ sec. 15 T. 23 N., R. 3 W.

The discovery well was drilled in 1918 on the Barnes farm in the N. W. ¼ sec. 15. The initial production was reported from 100 to 400 barrels from a sand at a depth of 2,037. Considerable excitement followed and soon afterwards about 12 wells were drilling in proximity to the producer. In the latter part of 1918 and the early part of 1919 seventeen wells had been drilled. Of this number only 4 found production and the remainder were dry holes. No wells have been drilled below the Barnes sand. Dry holes practically surround the small producing area.

The well record for Kay county for the years 1912 to 1918, not including the Garber, Billings nor Barnes pools is as follows:

WELL RECORD FOR KAY COUNTY, 1912-1918.

	Wells Completed				Initial Production	
Year	Total	Oil	Dry	Gas	Total	Average
1912	58	31	20	7	4,790	154.5
1913	55	29	23	3	2,964	102.2
1914	113	58	49	6	5,417	93.4
1915	32	16	10	6	1,630	101,9
1916	52	30	9	13	8,060	268.7
1917*	104	74	15	15	34,310	464.7
1918*	214	146	49	19	44,822	307.0

*Oil and Gas Journal.

For Garfield and Noble counties—Garber and Billings pools, the well record is as follows: (Oil and Gas Journal.)

	Wells Completed				Initial Production	
Year	Total	Oil	Dry	Gas	Total	Average
1917*	81	51	15	5	13,520	264.3
1918	340	231	76	33	46,912	203.1

*Includes last half of year only.

EAST CENTRAL OKLAHOMA DISTRICT.

This district is a large one, which occupies the greater part of the Arkansas valley region and includes all or parts of the following counties: Okfuskee, Seminole, Hughes, Pontotoc, Pottawatomie, Coal, Atoka, Pittsburg, McIntosh, Muskogee (southern extension), Haskell, Latimer, Le Flore and Sequoyah.

The rocks of this region are shales and sandstones of Pennsylvanian age. In a general way they are of the same age as the rocks in the producing areas to the north and northwest, but the lower portion of the rocks in this region are older than any of those farther north. The deposits represent near-shore and, in part, non-

marine conditions. Except for the Wapanucka limestone, at the base of the Pennsylvanian, limestones are absent from the section.

The folding is much more pronounced than in the region to the northwest and the topography is rougher. Several ranges of hills, known locally as mountains, occupy the synclinal axes while the anticlinal axes are in broad valleys or flats.

The geology of the region is discussed in a previous section of this book and at greater length in three reports.

(1) The Geology of the Eastern Choctaw Coal Field, by Joseph A. Taff and George I. Adams, Twenty-first Annual Report, Part 2, U. S. Geological Survey, 1900.

(2) The McAlester-Lehigh Coal Field, Indian Territory, by Joseph A. Taff, Nineteenth Annual Report, Part 3, U. S. Geol-Survey.

(3) The Geology of East-Central Oklahoma, by L. C. Snider, Bulletin No. 17, Okla. Geol. Survey, 1914.

Reference should be made to these reports for details concerning the structure and stratigraphy.

At first glance this region appears very favorable for both oil and gas but, with one or two minor exceptions, only gas and that in moderate amounts has rewarded drilling. The writer is of the opinion that the folding which has taken place has produced sufficient metamorphism to convert any oil, which may have been present in the rocks, into gas and to drive out the greater part of the gas. (See "Effects of metamorphism on accumulations of petroleum and natural gas" in Chapter 2 of this book.)

In the following paragraphs the development in each county is noted briefly.

Okfuskee county—Okfuskee county has had several test wells, some of them favorably located as regards structure, but no important pools have been developed. The Tiger Flats pool of Okmulgee county extends across the county line into Okfuskee. A small amount of gas has been found near Okemah. Considerable excitement was caused in 1914 by the finding of gas and a little oil in a well drilled near some faults, about 2 miles northwest of Paden. Further drilling has failed to show any accumulations of value.

Seminole county—A small quantity of oil was discovered at Wewoka in 1908, but further prospecting in the county has had only disappointing results.

Hughes county—Hughes county has shown no production except two or three scattered gas wells. Several dry holes have been drilled.

Pontotoc county—Near Ada, in the southwestern part of T. 4 N., R. 6 E., a dozen or more wells have produced gas from a depth of about 1,000 feet. The wells are of rather small volume; generally less than 5,000 cubic feet per day. Showings of oil were encoun-

tered but no oil production has been made. The field was most active in 1914 and 1915.

The Allen pool lies in secs. 23 and 26, T. 5 N., R. 8 E. The productive area is small. A heavy oil was found at a depth of about 800 feet. The wells had a small initial production ranging from 3 barrels to about 50 barrels per day.

Some encouraging showings have been found in other parts of the county but no important developments have come from them.

Pottawatomie county—In 1915, an oil well was drilled near Maud in the southern part of the county. The production was small and no development has resulted.

Coal county—The well developed anticlines in Coal county have been tested in several localities but have produced only moderate amounts of gas. The principal pool lies along the Coal-Pittsburg county line, on the Savanna anticline, in Tps. 2 and 3 N. R. 11 E. There are a dozen or more gas wells which had initial capacities of up to 12,000,000 feet. The gas is dry and gives no indication of oil. Several dry holes have been drilled in the immediate neighborhood.

Some gas has been found in other localities but the developments have not been important.

Atoka county—Only a few wells have been drilled in Atoka county and they have been dry holes.

Pittsburg county—The gas production along the line between Pittsburg and Coal counties has already been noticed. Some half dozen wells have been drilled near Quinton, in secs. 182 in T. 7 N., R. 18 E., on the Kinta anticline. The wells have capacities ranging up to 20,000,000 cubic feet per day. The gas is produced from different sands, from 1,600 to 2,300 feet in depth.

A few wells have been drilled at Blocker, west of Quinton and on th esame structure and some gas obtained.

Several wild cat tests have resulted in failures or in small gas wells. A very deep test was drilled by the Gypsy Oil Company in sec. 6, T. 6 N., R. 14 E. This well was abandoned at 4,303 feet, and for some time, was the deepest drilling in the state but has now been surpassed by a well in the Billings pool which is over 4,400 feet deep. A log of the Gypsy well is given in the appendix.

McIntosh county—There is a small oil production in the northwestern corner of this county, which may be considered as an extension of the Okmulgee district.

Much drilling has been done in other parts of the county but only comparatively small amounts of gas and a few showings of oil have been found.

Muskogee county—The southern extension of Muskogee county, which lies in this district, has some anticlinal structures near War-

ner and Porum. These have been drilled and only small amounts of gas have been discovered. No production has been made.

Haskell county—The anticlinal structures which cross Haskell county have been drilled, but like the rest of this district have shown only moderate quantities of gas. Some of the wells of the Quinton gas pool in Pittsburg county are over the line in Haskell county. Wells near Stigler and near Kinta have had some gas.

Latimer county—The only development in Latimer county is a small amount of gas 4 miles north of Red Oak. The field has been abandoned.

Le Flore county—The principal gas producing area in Le Flore county lies east of Poteau, in T. 7 N., R. 26 E., along the axis of the Poteau anticline. About twenty wells have been drilled, with initial capacities of as great as 18,000,000 cubic feet per day. Wells drilled a short distance from the axis of the anticline are very small producers or dry holes.

Some gas has been found in the northern part of the county near Spiro and Panama but the field is not active at present. Gas in considerable quantities has been found across the state line near Fort Smith, Ark., but no oil has been found.

Sequoyah county—A small quantity of gas was found in a well drilled near Vian several years ago. The gas was not utilized. Other wells drilled in the county have been failures.

SOUTHERN OKLAHOMA DISTRICT.

The Southern Oklahoma district as here considered includes the area south of the Arbuckle and Wichita mountains and between the two ranges. The region is underlain by Permian Redbeds which lie conformably over Pennsylvanian beds at a distance of a few miles from the mountains and on the truncated edges of Pennsylvanian and older rocks in the immediate vicinity of the mountains. The accumulation in all the pools is controlled by anticlinal structure, the localization of which is due probably to the presence of anticlinal ridges in the underlying pre-Pennsylvanian rocks. These conditions are discussed more fully under the Healdton field.

The following oil and gas pools are included in this district: Wheeler, Healdton, Fox, Two-four, Velma, Cement, Walter, Loco, Duncan, Lawton, Gotebo and Granite.

Wheeler pool—The conditions in the Wheeler pool were described in 1913 by F. Julius Fohs.* There has been very little development in this pool since that time since the pool has been completely overshadowed by the more important Healdton and Fee pools to the northwest and southwest. In the light of later developments in the region Fohs' statement of conditions is correct in practically all its features. Although unimportant commercially

*Quoted by Snider. L. C.. Petroleum & Natural Gas in Oklahoma, pp. 144-145.

the pool is of considerable scientific interest on account of its bearing on the accumulations in the other pools of the district. Fohs' description is therefore given in full.

"This pool, which derives its name from an unbuilt townsite in Wheeler township in northeastern Carter county, Okla., is representative in structural features of one of the two types found in the Redbeds, a domed anticline, being similar in character and parallel to but a shallower depth than the Petrolia pool in Texas. The other principal type of structure, developed in the Electra pool by Udden, shows that both the important structural types which control oil and gas accumulations are represented in the Redbeds.

"In a general way the anticline upon which the Wheeler dome is located strikes northwest-southeast, paralleling the general trend of the Arbuckle-Wichita uplift, and being directly in line with the Criner Hill uplift. It would appear therefore as probable that the direction of these post-Pennsylvanian uplifts was followed by later post-Permian folding of more gentle character, paralleling and following the old established lines of weakness. Cross-folding almost at right angles is responsible for the doming. The pre-Permian beds were very much more sharply folded, turned in fact almost upon edge, especially along the Criner Hill uplift as well as where the larger Arbuckle uplift is approached further north, so that the post-Pennsylvanian erosion which truncated them permitted the escape of most of the oil and gas contained, leaving them only the heavier residues in the form of the asphalt deposits. Thus drilling in this vicinity to greater depth than the base of the Redbeds whose maximum thickness in the Wheeler field is about 1,025 feet, appears unwarranted, and a sheer waste of money expended thereon. Heavy as this oil is—18 to 19 deg. Be.—it appears extremely reasonable that since there is sufficient in the way of shale-bed covering, to have prevented the escape of more volatile constituents, that the origin may best be attributed to a reconcentration of the oil residues obtained during the process of erosion of the pre-Permian beds. It appears more than co-incident that the heavy asphalt deposits along the north side of the Criner Hill uplift turned on edge as it is, should be directly in line with the Wheeler dome. Further it is worthy of note that the oil springs at the surface in the Wheeler field, together with asphalt rock croppings represent what were previously oil accumulations in these upper beds, a fact already generally recognized, but more than this, appear especially here because they were accumulations due originally to the dome structure, and therefore in a manner paralleling the main gas and oil sands below, facts that appear worthy of recognition in the search for other undeveloped pools.

"Three beds of commercial import appear in this field, the two upper ones being chiefly gas-bearing, the lower an oil sand with gas only at the crest of the dome. The uppermost lies about 385 feet above the second, and the latter 292 feet average above the lowest or principal oil sand. The depth to the top of the oil sand varies from 960 to 810 feet. The surface altitudes at the tops of the wells range from 1,010 to 1,078 feet.

"The main oil sand represents the basal sand bed of the Redbeds and varies in character from fine to very coarse almost gravelly sand, while its thickness varies from 10 to 60 feet, and locally is entirely absent either due to old near-shore channels or to its being deposited around old shale knobs, which means that even on the structure the oil is locally absent. The pool seems controlled by a dome where the top of the sand rises from 60 to 140 feet above sea level, without the 60-foot contour salt water being encountered while above the 125 foot contour gas rather than oil is present in all except one instance. The gas sands above are not strictly parallel, but appear to have the crest of the domes slightly to the southwest of that of the oil sand. The general trend of the anticline is northwest-southeast and the dome is necessarily elongated in that di-

rection, having a productive length of three times its width. The gas sands vary in thickness from 3 to 20 feet. Water sands occur irregularly through the measures and locally the deep sand has a water cap.

"Chances for profitable pools northeast and southeast toward the outcrop of the Redbeds appear negative, chances for small pools northwest where other domes are encountered are more encouraging, but of doubtful profitable character, while southwest where the Redbeds thicken, and parallel domed folds occur, the chancs are more promising, especially toward the Texas boundary line. We wish to acknowledge our indebtedness to the operators for their kindness in this investigation."

The developments since the above was written have consisted in the drilling of several more wells which are of the same character as the early ones. The wells are small producers of a heavy, black oil. The initial production ranged from 5 to about 70 barrels of oil and up to 13,000,000 cubic feet of gas. The oil has a gravity of about 20 degrees Baume. Both oil and gas are piped to Ardmore. The oil is not refined but is used as fuel by the Santa Fe Railway which controls all the development.

The first well was drilled in 1904, in sec. 21, T. 3 S., R. 2 W. By 1917, some 125 wells had been drilled, most of which were producers. Several attempts have been made to extend the production beyond the present limits and some deep wells drilled by the Santa Fe,

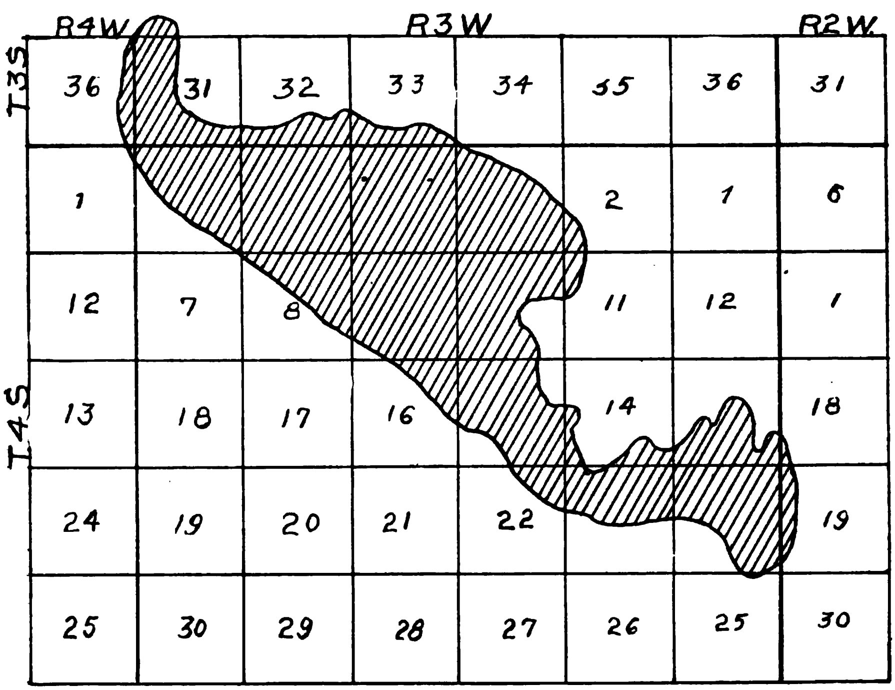

Fig. 82—Map showing producing area of the Healdton field.

failed to find any production below the 1,000-foot sand. From the well records it appears that the lower strata are steeply inclined. The development extends southeastward from the N. E. 1/4 sec. 17, to sec. 35 with practically all the production coming from the S. 1/2 of sec. 17, E. 1/2 sec 21, and S. W. 1/4 sec. 22, all in T. 2 S., R. 3 W.

Healdton field—By far the most important field of the southern Oklahoma district is the Healdton field, in western Carter county, which extends from the northwest part of sec. 31, T. 3 S., R. 3 W., southwestward across the north part of T. 4 S., R. 3 W., to the southeast corner of sec. 24. The producing area totals approximately 12 square miles. The developed area is shown in fig. 82.

This field has been rather fully described in two papers, one by C. H. Wegeman (Bull. U. S. Geol. Survey No. 621, 1915) and one by Sidney Powers (Econ. Geol. Vol. 12, No. 7, 1917.) Both these papers are used extensively in the following description.

A peculiar feature of the development is the straight line limiting the production on the southwest side of the field and the three-lobed effect on the northeast side. It is possible that future drilling may result in bringing these lobes together but at present this appears improbable.

The surface rocks of the Healdton field are soft sandstones, gray, yellow and red in color, and red shales all belonging, presumably to the Red beds of the Permian age.* These rocks are approximately 400 to 500 feet thicker over the Healdton field, and are underlain by gray to blue, Pennsylvanian shales and limestones with some sandstones from which the principal oil and gas production comes. The Pennsylvanian is underlain unconformably by Ordovician strata which seems to form a buried range of hills similar to the Arbuckle mountains and the Criner Hills except in that they do not reach the surface. This buried range of hills is responsible for the structure which controls the accumulation.*

The structure is a large, elongated dome with several minor folds superimposed. The minor folding has had a pronounced effect on the accumulation, the largest wells being on top. The minor

*The series of rocks exposed in the Healdton field and also in the larger structure in Tps. 3S, in Rs. 3 and 4W, are indistinguishable litholigically from rocks near Red River which almost certainly belong in the basal part of the Trinity sand of the Comanchean age. The writer thinks it entirely possible that at least some of the rocks, especially the gray sand series so prominent in the northern fold may be Comanchean in age although he is not able to prove the point. The basal Trinity sand naturally contains much reworked Permian material and the separation of the two systems is very difficult although they are separated by a considerable unconformity.

*For a full discussion of this point reference should be made to the paper by Powers cited above and others by the same author in Bull. Geol. Soc. Amer., Vol. 28, 1917, p. 159, and in Bull. Am. Inst. Min. Eng. No. 131, Nov. 1917.

structures are due to the unequalities of the old surface of the buried "Healdton Hills."

Wegeman in his report states that the structure is not indicated by the topography and gives the impression that it is not shown by the surficial rocks. In this, however, the writer cannot agree with him. The major part of the field lies on the high ridge which culminates at the township corner (Tps. 3 and 4 S., Rs. 3 and 4 W.). Also the surface rocks show unmistakable dips away from the axis of the structure. The bedding is so irregular that the minor structures can be made out with great difficulty if at all, but the main features are clearly shown. In making his contour map Wegeman depended entirely on correlation of sands by means of well logs. The sands are lenticular and it is very difficult to correlate them for any distance but the contour map prepared in this way probably represents the structure with a reasonable degree of accuracy.

The producing sands fall into two groups. (1) The Healdton sands which underlie the entire field at depths of 750 to 1,150 feet. These sands are from two to five in number, are lenticular and very variable in thickness and are intercalated with blue shale. The exact age of these sands is questionable, but they are either basal Permian or at the top of the Pennsylvanian. They have yielded no fossils. In the main part of the field the Healdton sands are underlain by Pennsylvanian limestone and shale which have not been productive of oil or gas. In the southeast extension, the Healdton sands are underlain by deeper sands which have been given special names, the Simpson and Jackson sands in sec. 15 and the Pugh sand in sec. 8.

These sands are known to be of Pennsylvanian age from the fossils contained in them, and are underlain at a short distance by rocks yielding Ordovician fossils, which probably belong to the horizon of the Simpson formation of the Arbuckle mountains. The deeper sands of the southeast extension are encountered at depths of from 1,150 to 1,860 feet. A well in sec. 4, T. 4 S., R. 3 W., found a small production of high gravity oil in an Ordovician sand at 2,716 to 2,749 feet. This is the only well in the field producing from known Ordovician rocks. Since these Ordovician beds are almost certainly very steeply tilted it is highly improbable that any production of importance will be obtained from them.

The first well was brought in in August, 1913, in the N. E. ¼ sec. 8, T. 4 S., R 3. W. This well was only a small producer (about 30 barrels) but attracted considerable attention and was the cause of an enormous lease excitement and of much drilling being started.

By the end of the year 14 wells had been drilled and the possible production was estimated at 20,000 barrels.

The history of the field since that time has been one of almost steady expansion and increase in production. The early development was retarded by lack of transportation and marketing facilities and it was necessary to run much oil into storage so that the stored oil amounted to about 2,000,000 barrels at the end of 1915. The building of the Magnolia Pipe Line and of the Oklahoma, New Mexico and Pacific Railway relieved this difficulty. The older part of the field has been well drilled and has fallen off greatly in production but so far the production of the field has been kept up by the discovery of new sands and new extensions from time to time. The most recent development is the southeast extension, with its deeper sands which has been noticed above.

It seems probable that the field is past its maximum production. The central part of the field has been tested for deeper sands but the presence of Ordovician rocks, apparently dipping at high angles, renders it highly improbable that there will be any deeper production in this portion of the field. The southern side and the northwestern end of the field seem to be well-defined. The limits of the southeastern extension have not been determined (1917) and there is some chance of deeper production on the north side and also of production in the known sands in the areas between the lobes on this side of the field.

The source of the oil in the Healdton field has been considerably in doubt. By many it has been considered that the oil probably migrated into its present position from the steeply titled early Paleozoic rocks below, but the evidence seems to favor the origin in the Pennsylvanian rocks themselves. The small amount of oil found in the Ordovician rocks may also have originated in the Pennsylvanian beds and have migrated downwards. This is by no means certain, however.

The character of the Healdton oil differs from that of the northeastern Oklahoma and Kansas fields in having an asphaltic base and a much lower percentage of the lighter constituents. Its value, therefore, is considerably less than the oils from the other Mid-Continent fields. The oil is generally black in color. The specific gravities of the oil from different wells varies from 25 degrees to 35 degrees Baume with much the greater portion of it about 30 degrees. In general the oil from the deeper sands is of higher grade than that from the shallow sands but there are many exceptions to this rule. The well record of Carter county, including the Healdton and Wheeler pools is shown in the following table. The development in the Wheeler pool since 1913 is practically negligible in comparison with that of the Healdton pool.

WELL RECORD OF CARTER COUNTY (HEALDTON POOL.)

	Wells Completed				Initial Production	
Year	Total	Oil	Dry	Gas	Total	Average
1913	23	15	5	5	844	56.2
1914	392	340	43	9	106,171	312.3
1915	318	289	22	7	85,320	295.2
1916	685	663	17	5	83,940	126.6
*1917	507	487	15	5	41,822	100.3
*1918	269	179	67	23	9,280	51.3

*Oil and Gas Journal.

Fox field—The Fox field is located in T. 2 S., R. 3 W., Carter county, Oklahoma. It is at present (March, 1919) confined largely to sections 20, 28, 29, 32, 33 and 34. Most of the production is gas though considerable oil has been found. The initial production of individual gas wells in the Fox field ranges from 30,000,000 cubic feet to 50,000,000 cubic feet of gas, and the initial production of individual oil wells from 40 barrels to 50 barrels. The main productive horizon lies at a depth of approximately 2,000 feet. The production is very spotted and the well-logs show much variation in the deeper rocks within very short distances. The surface shows a well-developed anticlinal structure and the lower rocks seem to have much steeper dips than those at the surface. The wells start in Permian rocks and the production is probably from the Pennsylvanian.

Two-Four pool—The two-four pool is located in T. 2 S., R. 4 W., Stephens county, Oklahoma. The production at present (March, 1919) is confined to sections 13, 14, 23 and 24. Some shallow production has been found in section 19, T. 2 S., R. 3 W., and it looks as if there may be an extension of the Two-Four pool in this township. There are at present about 100 producing wells in the Two-four pool. The production for the most part is oil, the wells coming

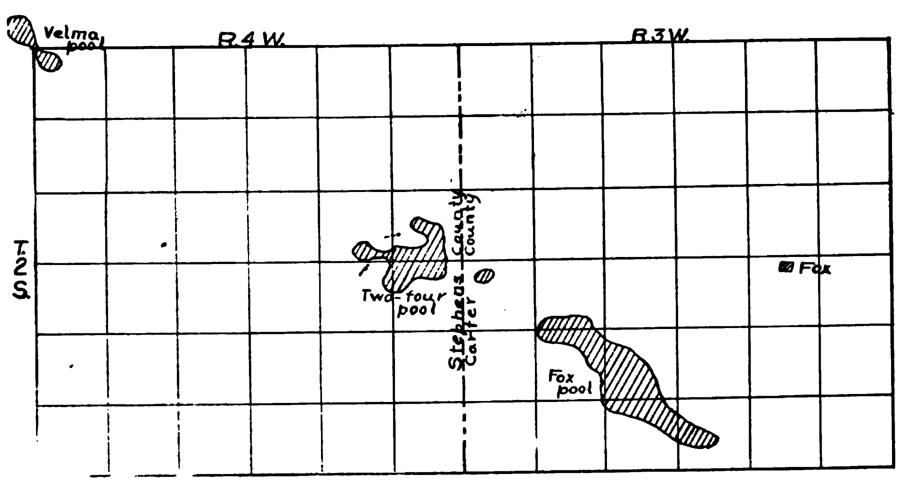

Fig. 83.—Map showing producing areas of the Fox, Two-Four and Velma pools.

in with an initial production of from 6 to 200 barrels. Productive horizons are found at the following depths: 300, 525, 600 and 1,050. Most of the production at present is from the shallower sands, only one or two wells having been drilled deep enough to encounter the 1,050 foot horizon. The pool is located on the western extension of the structure on which the Fox pool is located and the general geologic conditions are the same as in that pool.

Velma Pool—The Velma pool as developed at present (March, 1919) is in section 36, T. 1 S., R. 5 W., and section 1, T. 2 S., R. 5 W., Stephens county, Oklahoma. Both gas and oil are found, but as only a few wells have been drilled it is impossible to predict the future of the field.

The productive horizons are at a depth of approximately 500 and 600 feet.

The pool is located on the crest of the same large anticlinal structure which extends from T. 2 S., R. 3 W., across T. 2 S., R. 4 W., and which controls the accumulation in the Fox and Two-Four pools. The location and producing areas of the Fox, Two-Four and Velma pools are shown in fig. 83.

Cement field—As developed at present (March, 1919) the Cement field is located in section 31, T. 6 N., R. 9 W., section 36, T. 6 N., R. 10 W., and section 6, T. 5 N., R. 9 W., Caddo county, Oklahoma. There are about four producing wells in this field at the present time. The Fortuna Oil Company's, Gregory No. 1 in the W. ½, S. W. ¼, section 31, T. 6 N., R. 9 W., had an initial production of 30,000,000 cubic feet of gas. The initial production of oil wells ranges from 60 to 125 barrels. The main productive horizon is at a depth of about 2,300 feet.

Walters field—The Walters pool as developed at present (March 1919) is located in T. 1 S., R. 8 W., T. 1 S., R. 9 W., T. 1 S., R. 10 W., and T. 2 S., R. 10 W., in Cotton and Stephens counties, Oklahoma. There are at present about 30 producing wells in this field. Both oil and gas are produced. The initial production of individual oil wells ranges from 20 barrels to 285 barrels, and some of the gas wells have an initial production of as high as 60,000,000 cubic feet. The productive horizon is at a depth of about 2,150 feet.

The surface rocks are Redbeds and the exposures are few. However an anticlinal structure seems to be indicated.

Loco gas pool—The Loco gas pool lies along the border of Stephens and Jefferson counties in the east-central part of T. 3 S., R. 5 W. No oil has been produced from this field but several gas wells with initial capacities of up to 20,000,000 feet hace been drilled. The productive area is on the southeastern end of an anticlinal fold and includes all or parts of sections 9, 10, 14 and 15 T. 15, T. 3 S., R. 5 W. The productive sands are at depths of 650 to 750 feet below the surface and are thought to lie at the base of the Permian. Deeper

wells which have penetrated the underlying Pennsylvanian have had showings of oil and gas. The field was first drilled in 1913. Attention was attracted to the area by the presence of asphalt seeps which had been known for many years.

The field is now largely controlled by the Lone Star Gas Company which has a pipe line connecting with their main line from the Petrolia field to Dallas and Fort Worth.

Duncan gas pool—The Duncan (also known as the Hope and the Cruce) gas pool lies at the north end of a plunging anticline, principally in section 12, T. 1 N., R. 6 W. About a dozen gas wells with initial capacities of from 3,000,000 to 18,000,000 cubic feet per day have been drilled. The production comes from a depth of about 850 feet. The general geologic conditions are similar to those of the Loco pool. The gas is piped to Duncan and neighboring towns but the supply is scarcely sufficient to furnish this local demand in cold weather.

Lawton pool—The Lawton pool is located about 5 miles east of the city of Lawton. The first well was drilled in 1904 and drilling has been almost continuous since that time, but it has been on a small scale and the field has never attracted a great deal of attention. Twenty barrels per day is reported as the maximum production of a single well. Some of the gas wells have capacities of up to 500,000 cubic feet. The gas is piped to Lawton and the supply has not been in excess of the demand for domestic purposes. The production is from sands near the base of the Redbeds at about 320 to 400 feet below the surface.

Gotebo pool—A considerable number of wells have been drilled south of Gotebo in northwestern Kiowa county. The geologic conditions are practically the same as for the other pools in the Redbeds area near the Arbuckle and Wichita mountains. The surface rocks are Redbeds sandstones and shales with some conglomerate. These rocks lie nearly level and lap over the granite and older Paleozoic rocks which are exposed in the mountains. Most of the wells are from 300 to 400 feet deep. The oil and gas probably are derived from the older rocks below the Redbeds. The structure of the pool has not been determined. The production of the wells is small and none of the gas wells have shown more than 500,000 cubic feet daily capacity and the oil wells have less than 20 barrels initial production. Over 150 wells have been drilled, of which the greater part are oil wells.

Development of Granite—During the years 1901-1906 seven wells were drilled in the vicinity of Granite in northeastern Greer county. One well on the townsite encountered granite at 380 feet and drilling was stopped. A well northwest of town found oil at a depth of about 180 feet, but the production was only about 3 barrels per day of a heavy oil. In an effort to increase the production

by shooting, the well was destroyed. The other wells in the same vicinity were lost. A deep well about 7 miles north of town was drilled to a depth of 2,135 feet. Several sands were encountered and several good showings of oil and gas were reported, but no production was developed. The Redbeds in this well had a thickness of about 900 feet, showing that the thickness increases very rapidly to the north of the mountains. Only sandstones, shales and conglomerates were reported in the log.

In April, 1919, a well was completed in section 25, T. 7 N., R. 21 W. north of Granite. It is reported as good for 50 barrels of oil, and as having a good flow of gas, but to be making some salt water. The depth is 978 feet.

RED RIVER LIMESTONE AREA.

The geologic conditions of this area with reference to the accumulation of oil and gas have been discussed rather fully in a previous section and the remarks need not be repeated here. The only development in the region which has attained any importance is the pool at Madill.

Madill pool—The Madill pool was discovered in the summer of 1906. The principal development was on the Arbuckle farm in the S. W. 1/4, sec. 25, T. 5 S., R. 5 E. Considerable drilling was done, but the pool was never extended very far beyond the limits of the Arbuckle farm and the number of producing wells was never very great. There has been no marked development in the pool since about 1910 when there were only a few producing wells out of a large number of holes that had been drilled. The production was never very large and for some time was between one and two tank cars per month. Recently the production has practically ceased on account of the sands becoming clogged with paraffin. The highest initial production of any of the wells was reported at 1,000 barrels, but according to some observers did not exceed 400 barrels. The oil is a very light oil, having a specific gravity of 47.5 degrees Baume, making it by far the lightest oil so far found in Oklahoma. The base is pure paraffin with no trace of asphalt. On distillation the crude yields about 60 per cent light oil, of which almost one-half is gasoline. The oil is shipped in tank cars from a loading switch near Madill.

About 1912 a small deposit of heavy oil was found near Mannsville, which attracted some attention but nothing important developed. Some gas was found near Lark, west of Kingston, but the field proved to be very small.

The district has been pretty well tested and the probabilities of finding any large pools seem to be very small.

OIL AND GAS FIELDS OF TEXAS.

As has been stated, only those fields in Texas in which the oil and gas occur under conditions similar to those of the fields of Kansas and Oklahoma, are considered in this book. The Gulf Coast dome pools differ in so many ways from the other pools that they cannot be considered as coming in any way under a discussion of the Mid-Continent fields. Certain pools in the Cretaceous area of Texas may in a way be considered intermediate in type between the typical Mid-Continent fields and the Gulf Coast domes, but their relations to the folds of the Pennsylvanian-Permian area are much closer than to the domes and they are considered in this connection. The principal pools of the type just mentioned are the Corsicana, Mexia-Groesbeck, and the Caddo pool of Louisiana and Texas. For convenience of discussion the production of the Pennsylvanian Permian area are considered under the counties in which they occur. The principal producing counties are:

Wichita—with the Electra and Burkburnett pools.
Clay—with the Petrolia pool.
Palo Pinto—with the Mineral Wells and Strawn pools.
Stephens—with the Caddo and Parks or Breckenridge pools.
Eastland—with the Ranger field.
Comanche—with the Duke or Desdemona pool.
Brown—with the Brownwood shallow pool.

Several other counties have some small development and these are also noted briefly.

The development in the Cretaceous and Gulf Coast areas are described under the pools, which are:

Corsicana oil and gas field.
Mexia gas field and
Thrall oil field.

The Caddo field extends into Texas for a short distance but is considered under Louisiana. Several minor occurrences of oil or gas in this region are noted briefly.

PENNSYLVANIAN-PERMIAN AREA.

Wichita and Clay Counties.

ELECTRA-PETROLIA DISTRICT.

The Electra-Petrolia district is located near Red River in Clay and Wichita counties, extending from the Wilbarger-Wichita county line about 3 miles west of Electra, eastward across Wichita county and into northern Clay County to 4 or 5 miles of Petrolia. The total length of the district is about 35 miles.

The surface rocks are the Redbeds of the Wichita formation and consist of red shales with thin, lenticular, cross-bedded sands. There are no beds within the area which are persistent enough to

be correlated from place to place and the determination of the structure at the surface must depend on the interpretation of local dips. These are short and more or less conflicting but seem to show a broad, low fold with its axis extending as described above.*

The Permian rocks, principally Redbeds, are supposed to be about 900 to 1,000 feet deep. The underlying rocks are, for the most part, Pennsylvanian in age, but the lines between the formation exposed farther southeast have not been drawn. Some thick limestones in the deeper drillings have generally been considered to represent the Canyon formations, while it has also been suggested that the deepest limestones represent the Arbuckle or Ellenberger limestone and that the structure of the district is due to a buried range of hills of the Arbuckle mountain type.

Both the Standard and Rotary methods of drilling are used, as well as combinations of the two methods. In many wells the Rotary is used for most of the depth but the cable tools used to drill through the zones where production is probable.

The district comprises the following pools: Electra, Burkburnett, Holliday, Iowa Park and Petrolia. These are described briefly in the following paragraphs.

The location and approximate size of the producing areas are shown on fig. 84.

Electra pool—The Electra pool is located in the west central part of Wichita county. The productive area occupies a belt about 10 miles long east and west, with an average width of about 4 miles, and a second somewhat smaller area lying to the south with its long axis extending in a north and south direction.

Development began in 1911 and has continued uninterruptedly to the present.

The oil sands fall into three groups according to Udden.*

The Deep Group sands lie deeper than 1,700 feet. It consists of several sands, all of which are more or less lenticular and not of great thickness.

The Middle Group sands lie at about 1,000 feet. In most wells there are two sands in this group although several strays are reported. The two main sands also seem to split into thin sand beds separated by clays.

The Shallow Group sands are between 500 and 700 feet below the surface. They have not been very productive in the Electra pool, and are generally very lenticular.

In general the shallow sands have given small wells, less than 100 barrels initial production. The deeper sands have been more

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*Op. cit. pp. 96 et. seq.

*Udden, J. A. Reconnaissance report on the geology of the oil and gas fields of Wichita and Clay counties, Texas. Univ. of Texas Bull No. 246, 1912.

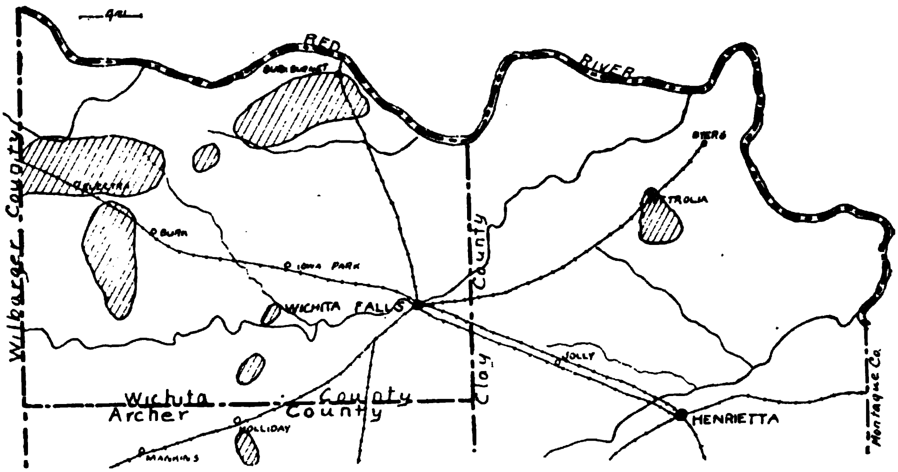

Fig. 84.—Map showing producing areas in the Electra-Petrolia district.

prolific, many of the wells having been of the gusher type and having initial productions of as high as 1,500 barrels per day.

The oil from the Electra pool is of high grade averaging about 41 degrees Baume in gravity and containing practically no sulphur or asphalt.

Burkburnett pool—For all practical purposes the development in the vicinity of Burkburnett may be considered as part of the Electra pool, with which it is practically continuous. The same group of sands are productive and show the same lenticular and broken character. The depth to the sands becomes slightly less toward the east. The character of the oil and the size of the wells is about the same as for Electra.

Quite recently, in the summer of 1918, oil was discovered on the Burkburnett townsite and the resulting "boom" has been undoubtedly the most feverish so far in the Mid-Continent fields. On account of the enormous interest which this pool has attracted rather than on account of its real importance the following detailed account of the conditions is given.

THE BURKBURNETT OIL FIELD.

By L. W. KESLER.

Burkburnett, Texas, is located in the northeast quarter of Wichita county, approximately one and one-half miles southwest of the Red river, and fourteen miles west of north of Wichita Falls, Texas, on the Wichita Falls and Northwestern Railroad. The townsite of Burkburnett is approximately 3,500 feet long and 1,900 feet wide and comprises forty blocks, eight blocks long and five blocks wide. The Burkburnett Oil Field includes this townsite and

the surrounding country for a distance of from two to three miles.

The field is located physiographically in the northeastern part of the North Central plains of Texas, approximately 55 miles west of the Grand Prairie region, and 125 miles east of the Llano Estacado or Staked plains. It is due north of the Central Mineral (Llano-Burnet) region of Texas.

The surface rocks or formations covering this part of Texas are entirely of Permian age. No rock outcrops occur in close proximity enough to the field to permit the determination of the structure nor the probable size of future extent of the field. Much can be and has been accomplished however, by means of subsurface geology or by the use of logs of wells drilled to the present time. The following data has been obtained by the latter method.

There is but one producing sand of any consequence in the townsite and areas in close proximity. This sand is found at depths varying from 1,518 to 1,735 feet, and has a thickness varying from 15 to 60 feet. Over most of the area, however, it varies from 30 to 50 feet in thickness. There are very few breaks of clays or shales found in the sand. The thickness is not as great on the southwest of the townsite, some of the sand being replaced by blue shales and thin limestone.

The elevation of most of the producing wells in the townsite is from 1,055 to 1,060 feet above sea-level. This will vary in a few cases from 970 to 1,080 feet. Logs of the field show that the rocks dip northeast on the northeast side of the townsite, and wells located too far in northerly and easterly directions run into salt water. The highest point in the sand so far drilled into is at the southwest corner of the townsite. The dip is east and west from this point. Further information at this time is not available.

For several years, petroleum has been found on various occasions within a few miles of the Burkburnett townsite and production in the vicinity at the time the "Discovery" well was drilled into the sand, amounted to several thousand barrels per day. One of the first of these wells to come into production in the northern part of Wichita county, after the Electra oil field, was the No. 1 Smoker, drilled by the Magnolia Petroleum Company in block 30 of the Red River Valley Lands.

But the real "Discovery" well of the Burkburnett townsite was the Fowler well located on the northeast edge of the townsite. This well was drilled by the Fowler Farm Oil Company, organized by Mr. S. L. Fowler with local capital and capitalized at $12,00.00 on an acreage of approximately 300. It was drilled into the oil sand between July 18 and July 22, 1918, and had an initial production around 2,000 barrels per day. It may be said that this well was the beginning of activity which, within the brief period of six

months, brought about one of the best known and, in many ways, the most remarkable oil boom ever known in the United States.

During the period while the Fowler "Discovery" well was drilling, leases were being taken in the vicinity at about $.25 per acre. In January, 1919, six months later, one small lease in the townsite proper is reported to have sold at the rate of $20,000.00 per acre. There are few oil and gas leases, if any, in the world which have brought such fabulous figures. At the present time it is not uncommon for leases with no production and not located where production is certain, to sell for $15,000.00 per acre. Such excessive prices for acreage are obtained only in the Burkburnett townsite, but it holds true that acreage throughout the whole of Wichita county is held at an extremely abnormal rate.

The value of the land as represented by the capital stock of some of the smaller companies is much greater than this.

During the first period of the field oil companies were formed at low capitalizations and on sufficient acreage to be attractive propositions to the conservative investor, but as the field grew capitalizations increased and acreage decreased until it is now not uncommon to note companies formed with capitalizations of from $80,000.00 to $100,000.00 and a total acreage of less than half an acre.

The production of the Burkburnett Oil Field (Townsite and surrounding country) by months from the opening of the field through January, 1919, follows:

July 1918	17,774	Bbls.	per	day
August, 1918	19,414	"	"	"
September, 1918	23,720	"	"	"
October, 1918	21,577	"	"	"
November, 1918	28,771	"	"	"
December, 1918	38,221	"	"	"
January, 1919	45.141	"	"	"

The above production for January of 45,000 bbls. per day was produced by 1,650 wells, both shallow and deep. Of this production, approximately 35,000 bbls. are free oil (can be sold to any buyer) and approximately 10,000 bbls. are controlled by the following companies:

Magnolia Petroleum Co.	2,500	Bbls.
Texas Co.	1,000	"
Panhandle Refining Co.	1,900	"
Humble Oil and Ref. Co.	2,800	"
Gulf Pipe Line Co.	1,050	"
C. B. Farquharson	235	"

The total production of 45,000 bbls. per day is purchased by the following companies:

Magnolia Petroleum Co.	8,440	Bbls.	per	day
Texas Co.	11,300	"	"	"
Panhandle Refining Co.	4,400	"	"	"
Burkburnett Refining Co.	2,000	"	"	"
Humble Oil & Refining Co.	4,400	"	"	"
Liberty Pipe Line Co.	3,200	"	"	"
Western Oil Corporation	4,600	"	"	"
Crude Oil Marketing Co.	2,300	"	"	"
Gulf Pipe Line Co.	2,800	"	"	"
Southwestern Petroleum Co.	200	"	"	"
Hockaday Pipe Line Co.	675	"	"	"
	44,315			

The above companies shipped out of Burkburnett during the month of January, 2,300 tank cars, a total of 572,000 barrels of petroleum. Petroleum received by the pipe lines for the same month amounted to 1,355,000 bbls.; that delivered by the pipe lines, 1,352,000 bbls.; stock on hand, January 1, 1919, 155,000 bbls.

Two typical logs of wells in the Burkburnett townsite are given in the appendix.

One of these is that of the Taylor No. 1, Gulf Production Company, located twenty feet each way from the northeast corner of block No. 34, town of Burkburnett. Drilling was begun on this well August 8, 1918, and completed Nov. 12, 1918. The oil sand was reached at a depth of 1,682 feet and was drilled in for 15 feet, making a total depth of 1,697 feet. Its initial production was 200 barrels per day. On Feb. 19, 1919 (latest report available) it was still holding up to its initial production.

The other log is that of the Gillis No. 1, R. O. Harvey, et al, located 150 feet each way from the northeast corner of the south five acres of outer block No. 15, town of Burkburnett. Drilling was begun August 15, 1918, and completed August 31, 1918. The oil sand was entered at a depth of 1,657 feet and drilled into for 26 feet, making a total depth of 1,683 feet. Initial production of this well was 1,500 bbls. per day. On Feb. 19, 1919, the production had decreased to 640 barrels.

The boundaries of the Burkburnett pool are fairly well determined except on the north-west. The field is still being extended in this direction with considerable success. On the northeast or Red river side, the pool may possibly extend across the river, but this seems doubtful due to the strong northeast dip here shown by sub-surface results previously mentioned, and also due to the fact that several wells located too close to the river on the Texas side have run into salt water.

On the southeast of the field, the Humble Oil and Refining Company have completed two tolerably deep test holes both dry. One is the W. C. Myers No. 1, 200 feet each way from the northeast corner block No. 5, Red River Valley Lands survey. This well was

dry and abandoned at 2,300 feet. It is approximately 2½ miles southeast of the Burkburnett townsite. The other Humble test is the C. S. Maxwell No. 1, dry and abandoned at 2,007 feet, 250 east, 25 feet south of the northeast corner of block No. 104, Red River Valley Lands Survey, and located in block No. 1, John Deck Survey. This well is slightly less than two miles south-east of the Burkburnett townsite and approximately one mile north of the W. C. Myers No. 1 previously mentioned. These two tests aid materially in determining the boundaries of the field on the southeast side. Logs of these wells are given in the appendix.

On the south and southwest sides of the field, there were on Feb. 1, 1919, eleven dry holes evenly distributed on a northwest-southeast line over two miles long. This line passes the southern corner of the townsite at approximately 1,000 feet distant, and may be considered as a distinct and well determined boundary of deep production on the south and southwest sides. Shallow production, however, extends farther to the south.

At the present time the production of the Burkburnett oil field as a whole is slightly on the increase. The apparent reason for this is because of the large number of new wells which are constantly being drilled into the sand, and because of the fact that the total production includes that of many shallow wells about the outskirts of the field proper (mostly south and southwest). These shallow pools are now getting much of the attention and development which, 3 months ago, was going into the deeper and larger wells more centrally located in the field.

The townsite has gone through that history which all oil fields go through, particularly those controlled by the small operator, namely, the location of far too many wells to the acre. Every little building lot has a rig upon it; every back door yard has a well all its own; and to look at the townsite from a distance, the stranger would swear that the legs of the derricks were "crossed." The fact is, many derricks are set up 20 feet apart. One derrick is squeezed in between two little houses, so that the legs are within a foot of a house on either side.

The inevitable result has already come upon the townsite. The production of the wells on the latter is beginning to decrease, and, in many cases, very rapidly. Without doubt, the center and heart of the field has gone over the top and is well on the downward path. The thickness of the sand is sufficient to give much production for some time to come, but the "flush" production must necessarily decline very rapidly with so many wells in the sand.

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During the early summer of 1919 the principal interest in the Burkburnett field was transferred to the northwest extension where

*Shaw, E. W., Gas north and west of Ft. Worth. Bull. U. S. Geol. Survey No 629. pp. 25-41. 1916.

the conditions just described for the townsite have been repeated. The northwest pool is still undefined (Aug. 1, 1919) and its true capabilities are not known on account of the lack of pipe-line facilities. It is capable of making a very large production, however.

Iowa Park pool—There has been some development near Iowa Park in the south central part of Wichita county. The production has been principally in the shallow sands and the wells have been small producers.

Holliday pool—The Holliday pool lies in Archer county, just south of the Wichita county line and north of the town of Holliday. The producing area is small and the wells of very moderate size. The production is about 100 barrels per day.

The well record for Wichita county since 1911 is shown in the following table which reflects the history of the field very closely.

RECORD FOR WICHITA COUNTY, TEXAS, 1911-1918.

Year	Well Record Total	Oil	Dry	Gas	Initial Production Total Bbls.	Avg. Bbls.	Marketed Production Bbls.
1911	53	51	1	1	15,550	304.9	899,579
1912	326	259	66	1	26,932	104.0	4,227,104
1913	561	435	125	1	49,286	113.3	8,131,624
1914	567	394	169	4	21,917	55.6	8,227,968
1915	156	124	29	3	5,488	44.3	5,883,951
1916	441	372	65	4	44,253	119.0	7,837,386
*1917	758	605	151	2	44,718	70.2	9,625,037
*1918	936	721	215	-	69,791	96.8	11,669,422

*Oil and Gas Journal.

*Petrolia field**—The Petrolia field, also called the Henrietta field, lies just south of the town of Petrolia in northwestern Clay county. The producing area is roughly elliptical extending about 4 miles from southeast to northwest and 3 miles in the opposite direction.

The general geologic conditions are entirely similar to those of the Electra and Burkburnett fields, except that the productive groups of sands are at somewhat less depths than in those pools.

A group of sands lying at from 150 feet to 300 feet below the surface give small but long-lived oil wells and very little gas. The deeper sands give large volumes of gas under high pressure and very little oil. The principal gas-producing sands are from 1,500 to 1,750 feet below the surface. The gas wells had initial volumes of from 10,000,000 to 40,000,000 cubic feet per day, and closed pressures of as high as 470 pounds per square inch. The pressure and initial capacities of new wells are now about one-half of the original magnitude. The Petrolia field is the oldest in northwestern Texas. The first oil was shipped in 1904 although oil had been known in shallow wells for several years previously. From 1904 to 1907 the development consisted entirely of oil from the sands at about 300 feet. In 1907 the first gas well was brought in and the pool has since been more important as a gas producer than

for oil. The gas produced to 1916 is estimated at 50,000,000,000 cubic feet. The gas is piped to Fort Worth and Dallas.

The following table gives a summary of the field operations of the field since 1905 and statistics in regard to the oil production.

RECORD FOR PETROLIA (HENRIETTA) FIELD, 1908-1918.

Year	Well Record				Initial Production		Marketed Production
	Total	Oil	Dry	Gas	Total Bbls.	Avg. Bbls.	Bbls.
1908	26	19	5	2	---	---	211,117
1909	46	20	15	11	484	24.2	180,764
1910	72	35	37	--	1,331	38.0	137,331
1911	19	7	9	3	69	9.9	128,526
1912	20	6	10	4	315	52.5	233,282
1913	171	122	45	4	2,676	21.9	158,830
1914	126	80	32	14	1,958	24.5	550,585
1915	8	4	1	3	273	68.3	349,857
1916	17	6	3	8	285	47.5	302,145
1917	19	8	8	3	1,050	95.5	273,229
1918	1	---	---	--	---	---	245,558

Archer county—The only development of note in Archer county is that near Holliday, which has been noticed as part of the Electra-Petrolia district.

In 1913, a small oil well was brought in in the southeastern part of Archer county, near the Young county line, but further drilling in the vicinity failed to find production.

Jack County.

Jack county is underlain by the rocks of the Pennsylvanian system. The Strawn formation outcrops in the southeastern portion; the Canyon formation in a belt diagonally across the central part of the county from southwest to northeast; and the Cisco formation in the northwestern portion. A few square miles in the extreme southeastern portion of the county is covered by the over-lap of the Trinity sands of the Comanchean.

The structure is normally a dip of about 60 feet to the mile in a general northwest direction. Locally, the dip is interrupted by gentle terracing and there is some faulting in the western part of the county.

The only production from Jack county has been a small quantity of heavy oil from the vicinity of Avis. Several wells have been completed but the production was very small and has been exhausted. A refinery of 300-barrel daily capacity was built at Avis in 1915 to utilize this oil which is said to be of exceptional value for lubricants, but the supply was not sufficient to keep the refinery running and other crudes had to be shipped in. Deep tests in the vicinity of the shallow oil have failed to give any favorable results.

Two deep wells in the vicinity of Cundiff, northeast of Jacksboro had no production to about 3,000 feet. A well near Vineyard, southeast of Jacksboro, was abandoned as dry at 2,680 feet. Two wells are drilling on the Cherryholmes ranch east of Jacksboro, one at 2,900 feet and one at 200 feet.

Young County.'

Young county lies immediately west of Jack county. The Canyon formation outcrops in the extreme southeastern portion; the Cisco formation covers the greater part of the county and the Wichita-Albany the northwestern part. The change from the non-red Albany facies to the red Wichita facies takes place largely in this county and the rocks in the northwestern corner are typical Redbeds. The structure is the normal northwest dip of the region with very few important variations from the normal.

There has been no production of either oil or gas. A well drilled to about 4,000 feet on the De Freest ranch in the southeastern part of the county near the Palo Pinto county line, had a small flow of gas and a good showing of oil, but failed to develop any production. A well near South Bend, southwest from Graham, also had some showings but is still drilling at about 4,000 feet Two wells in the western part of the county have also had some showings but are still drilling at 4,000 feet and 2,000 feet. Two or three other tests have been started but are not deep enough to give any results. One well recently (July, 1919), gave promise of being a very good producer, but finally turned out to be a small pumper.

Throckmorton County.

This county is underlain principally by the Albany-Wichita formation. The limestones and blue and gray shales in the southern part of the county grade into Redbeds in the northern part. The normal northwest dip is interrupted locally by small variations due to very gentle folding and also by small faults.

Two small gas wells were drilled on the Matthews ranch in the southern part of the county.

There is very little activity in the county at present.

Shackelford County.

The Cisco formation outcrops in the southeastern part of the county and the Albany or non-red facies of the Wichita formation forms the surface rocks over the greater part of the area. Variations from the normal northwest dip are few.

Moran pool—The only development of any importance in the county is the Moran pool in the extreme southeastern part of the county. The productive area is a short distance southwest of Moran. The surface rocks are shales and sandstones of Cisco age and do not show any pronounced structural changes from the normal dip. The productive sand is at a depth of about 2,500 feet. The oil is a fairly light oil averaging about 35 degrees Baume.

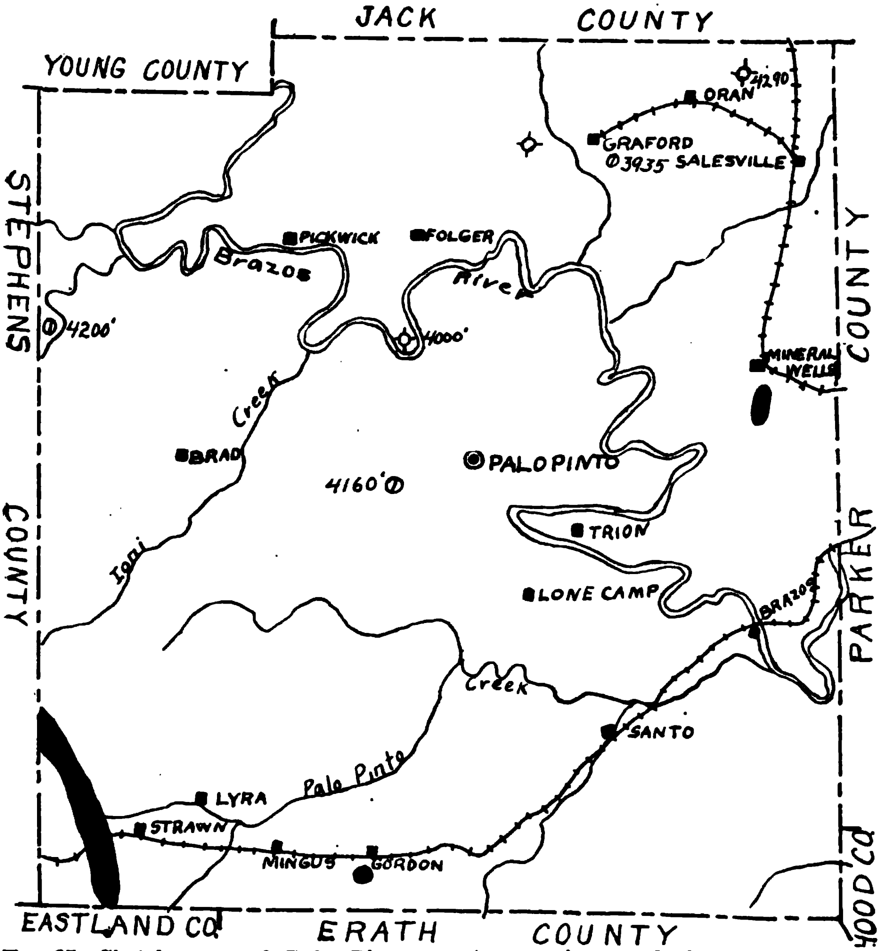
The first oil wells were brought in in 1913 when two wells, one with an initial production of 40 to 50 barrels and the other with 200 to 300 barrels, were completed. During 1914, 1915 and 1916, development continued but the results were more or less disap-

pointing since the productive area proved to be small and spotted, although quite a number of satisfactory wells were brought in. The production for the pool in 1916 was 135,608 barrels, or less than 400 barrels per day, and there has been considerable decline since that time.

Gas from the Moran pool is piped to neighboring towns but the supply is not large.

* * * * * * * * * * * *

Outside the Moran pool, wells are drilling near Albany. The deepest test is over 31,000 feet deep. It had a good showing at about 1,000 feet and this sand is to be tested by other wells. Some 4 or 5 other tests are drilling at depths between 200 or 300 feet and 2,200 feet.



Fg. 85—Sketch map of Palo Pinto county showing producing areas and approximate locations of deep tests.

Palo Pinto County.

Palo Pinto county is on the eastern edge of the Pennsylvanian area. Considerable areas in the eastern part of the county are covered by the overlapping sands of the Trinity division of the Comanchean. The outcrop of the Strawn formation occupies over one-half of the area of the county and the lower part of the Canyon formation makes a pronounced escarpment, known as the Palo Pinto mountains, in the western part. Variations from the normal northwest dip of the Pennsylvanian area are few and slight.

The productive areas in Palo Pinto county are the Mineral Wells gas field and the Strawn oil and gas field.

These areas and the approximate locations of the deep wells drilled in the county are shown in fig. 85.

Mineral Wells Gas Field.

(By F. W. REEVES AND W. C. BEAN.)

The Mineral Wells gas field is located south of Mineral Wells, three to four miles west of the eastern border of Palo Pinto county, Texas. The field extends about four miles in a north-south direction.

The first well in this field was drilled in 1915 on the farm of Mrs. J. E. Hess. In this well the producing sand was struck at a depth of 1,035 feet. Since that time about a score of wells have been drilled in this vicinity, twelve of which have produced gas, the production ranging from one to ten million cubic feet. None of these wells have produced any oil.

In the spring of 1917 a well on the J. A. Chestnut farm at the southern end of the field was completed, in which a gas sand was struck at a depth of 4,060 feet. This well produced about fifteen million feet of gas and a small quantity of high gravity oil.

The rocks exposed in the Mineral Wells gas field are mainly sandstone, blue and gray shales belonging to the Strawn series of the Pennsylvanian system. Occasionally thin limestones are encountered, interbedded with the sandstones and shales. Just east of the gas field a heavy bed of conglomerate outcrops, which also belongs to the Strawn series.

Near the southern end of the field the rocks exposed have a north-northwest dip of about 50 feet per mile. Farther north, in the neighborhood of the Hess wells, the dip swings to the west-northwest and becomes somewhat steeper. There are no closures in the surface contours in any part of this field. Contours on the thousand foot gas sand show a small terrace near the J. W. Glover and Noble wells and another terrace near the Edmondson No. 2 gas well. However, it seems probable that the accumulation of gas in this sand is due mainly to the lenticularity of the sand rather than to its structure.

As noted above, the gas in the Mineral Wells field comes from two different horizons, one at a depth of about one thousand feet and the other at a depth of 4,060 feet. The first sand varies in thickness from 5 to 35 feet. It thins rapidly toward the south and east and was not encountered in the Chestnut, Terry and Forbess wells. This producing horizon belongs to the Strawn series. In the Chestnut well a producing sand was encountered in the Bend series at a depth of 4,060 feet. Owing to the small size of the hole at this depth and to the gas pressure it was impossible to penetrate this sand more than a few feet. The gas from this sand carries a small amount of high gravity oil and it is possible that this horizon will produce oil on further development. This productive horizon was not encountered in the Oaks well three miles north of the Chestnut nor in the Smith well three miles east of Mineral Wells.

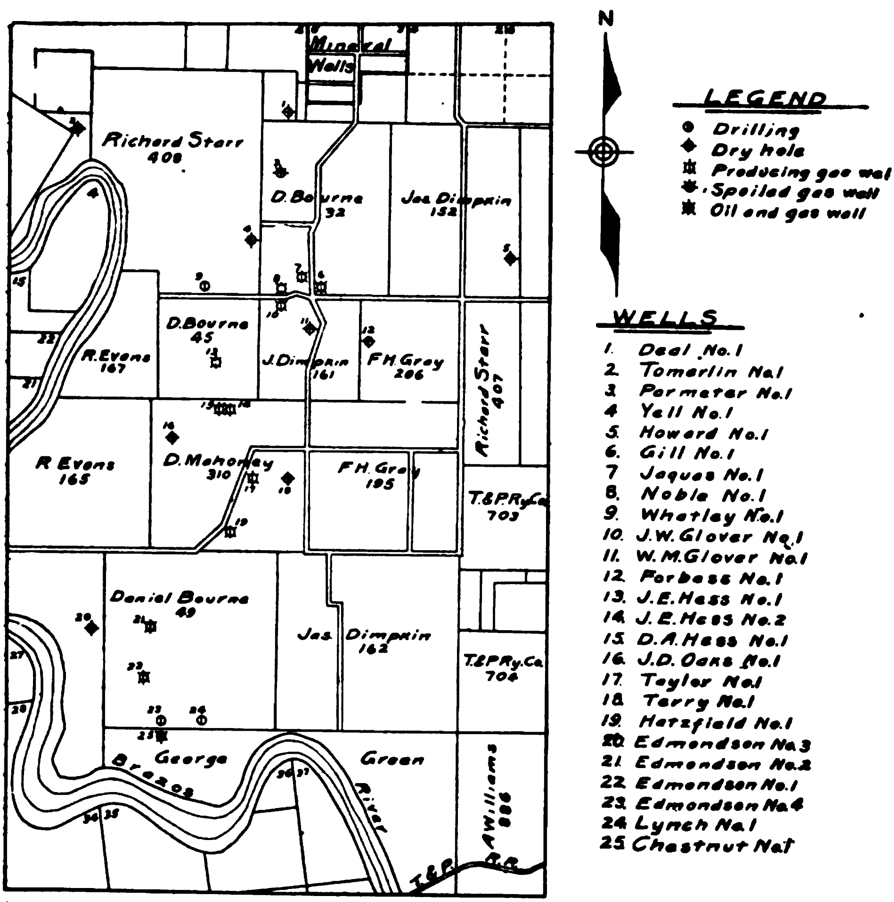


Fig. 86.—Development of the Mineral Wells gas field.

The gas from this field is distributed for domestic consumption in the city of Mineral Wells and is also used for fuel at the Acme Brick Works at Bennett.

The development in the early part of 1919 is shown in fig. 86.

* * * * * * * * * * *

Strawn pool—The Strawn oil and gas pool lies in the extreme southwestern part of Palo Pinto county. The productive area is a belt about one mile in width and 8 or 9 miles long, extending nearly north and south. The oldest and most thickly drilled portion of the field lies about 2 miles west of Strawn.

The surface rocks belong to the Strawn and Canyon formations. The structure as mapped by the United States Geological Survey* shows a small closing dome on a pronounced terrace. Other geologists have failed to find closing structure. The production is of both oil and gas, the gas wells being more numerous in the south part of the field. The productive horizon is at a depth of from 800 to 1,000 feet.

The first oil wells were drilled in 1915 and for the next year or two development was quite active but late in 1917, attention was transferred to the Ranger pool and the Strawn pool has been only moderately active since.

The following table giving the well record for Palo Pinto county for 1915 to 1917 shows the number of wells drilled, except the first gas wells and the average size of the wells as well as the production. The statistics include both the Strawn and Mineral Wells pools and the wild cat tests in the county. The northwestern end of the Strawn pool lies in Stephens county and these few wells are not included in this table.

RECORD FOR PALO PINTO COUNTY, 1915-1917.

		Well Record			Initial Production		Marketed Production
Year	Total	Oil	Dry	Gas	Total Bbls.	Avg. Bbls.	Bbls.
*1915	89	40	35	14	1,245	31.1	64,908
*1916	98	51	27	10	2,010	39.4	179,208
**1917	84	64	16	4	1,725	27.0	406,927

*Includes small production from other counties.
**Oil and Gas Journal.

Besides the wells in the Strawn and Mineral Wells pools several deep tests have been drilled in Palo Pinto county but with no important results.

A well was drilled on the Watson ranch in the bend of Brazos river north of Palo Pinto to a depth of over 4,000 feet, with no encouraging showings. A well near the crossing of the Palo Pinto-Breckenridge road over Eagle Creek is drilling at 4,160 feet. Two or three wells have been drilled near Graford and some oil was found but not in sufficient quantity to be worth development. A good

*Bull. U. S. Geol. Survvey No. 629, pl. III.

showing of oil was found at 4,200 feet in the Black Lime near the western edge of the county, but not sufficient to make a producing well. A well was drilled to 4,200 in the northeast corner of the county without any production.

Stephens County.

The surface rocks of Stephens county belong to the Canyon and Cisco formations of the Pennsylvanian. The county came into great prominence during the latter part of 1917 and 1918.

The principal development has centered around Caddo in the east-central part of the country and south of Breckenridge in the locality known as the Parks pool. The producing areas and principal wild cat tests are shown in fig. 87.

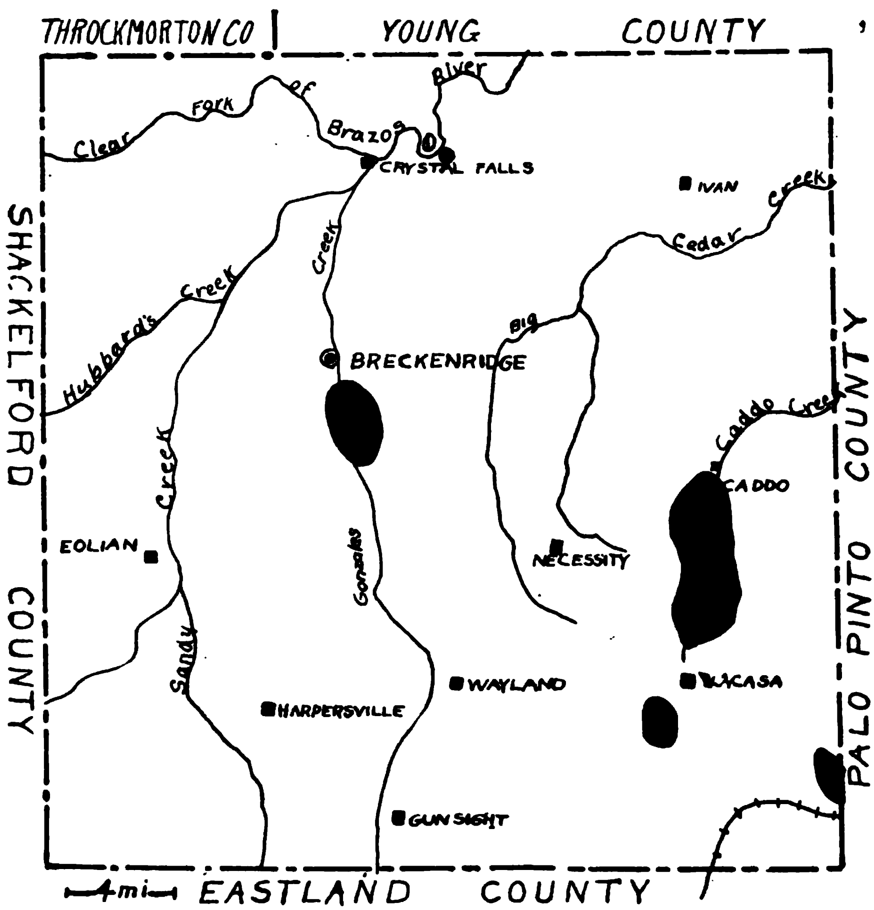


Fig. 87—Sketch map of Stephens county showing producing areas and approximate location of deep tests.

The Caddo pool was opened by a well about 1 mile south of Caddo in the summer of 1916. Since that time development has been rapid and by August 1, 1919, a number of wells had been completed. The production is from the Black Lime of the Bend series, and is found at a depth of about 3,300 to 3,500 feet. The initial production of the wells is as high as 8,000 barrels per day.

The Parks pool is located a few miles south of Breckenridge. The surface rocks show a well developed "nose" but the elevations of the Black Lime from which the production is obtained shows a much larger and more pronounced structure. The depth of the wells average about 3,500 feet. The oil is of high grade, about 37.5 degrees Baume. The activity in Stephens county is shown by the fact that, with practically no development in 1916 and only a few wells drilled in 1917, by the end of 1918 there were 29 producing wells, 18 dry holes and gassers, 18 wells shut down waiting storage, 147 wells drilling, 42 rigs waiting for machinery, and more than 200 locations made.* This, too, in spite of the fact that the greatest activity is a good many miles from a railroad and that during the latter months of 1918 the roads were practicably impassable.

The most recent important development is the discovery of oil in a well near Crystal Falls in the northern part of the county.

At the end of March, 1919, the reports from Stephens county showed producing wells as follows:

7 wells producing less than 25 barrels per day,
7 wells producing between 25 and 100 barrels per day,
24 wells producing between 100 barrels and 500 barrels per day,
5 wells producing between 500 barrels and 1,000 barrels per day,
3 wells producing over 1,000 barrels per day,

making a total of 46 producing wells with total average daily production of 18,197 barrels.

The most recent development has tended to bring the Caddo, Parks, Strawn and Ranger pools together into one large district. This area will undoubtedly have dry spots but, at present, it is difficult to define the individual pools.

Callahan County.

The eastern part of Callahan county is underlain by the sands and shales of the Cisco formation and the central and western parts by the limestones and shales of the Albany. The general dip is a little north of west at about 60 feet per mile and there are very few important variations from the normal dip.

The only encouraging results from drilling in the county have been in the eastern part near Putnam. In 1916 a well drilled to

*Oil and Gas Journal.

over 3,000 feet a short distance west of the town, had a small flow of gas and some oil showings. Early in 1919, a well drilled just southeast of town was reported to have a good showing at a depth of 3,680 feet, but failed to make a producer when completed.

Comanche County.

Comanche county lies to the southeast of Eastland county. Most of the county is covered with the Comanchean formations, principally the Trinity sands. The Strawn and Canyon formations of the Pennsylvanian occupy comparatively small areas in the northern and western portion of the county. The covering of Trinity sands makes it impossible to discover the structural conditions in the underlying Pennsylvanian in most of the county. An anticlinal fold is reported in the northeastern corner of the county and is thought to be responsible for the accumulation in the Duke pool.

The only development of importance to date is the Duke pool near the junction of Comanche, Eastland and Erath counties at the

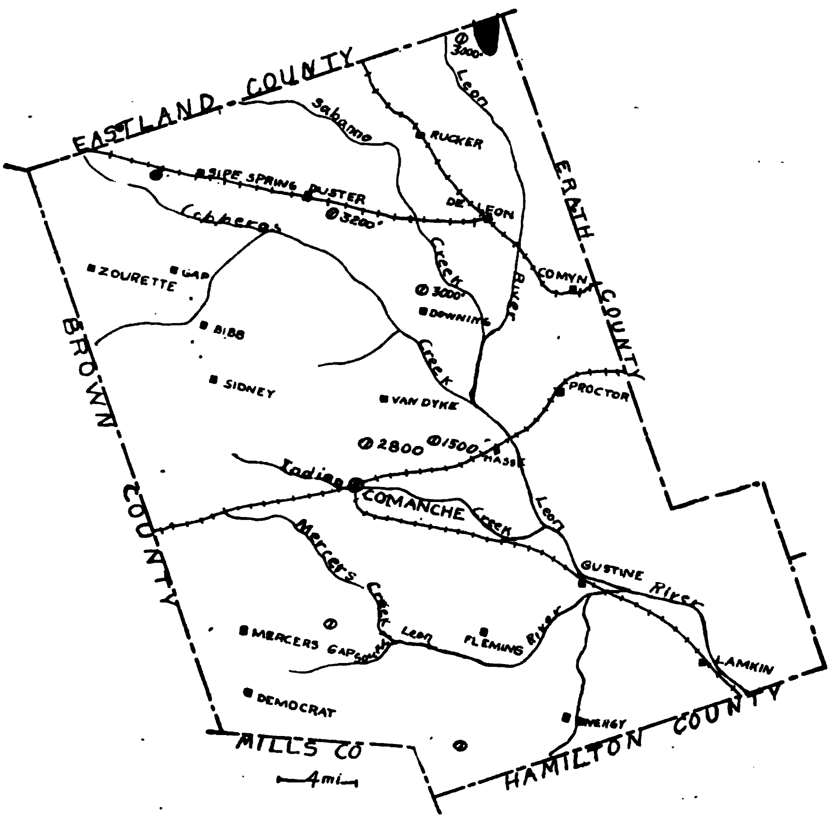


Fig. 88—Sketch map of Comanche county showing producing areas and approximate location of deep tests.

northeastern corner of Comanche. The discovery well, the Duke No. 1 was brought in during September, 1918. It had an initial production of about 400 barrels per day of oil similar to that of the Ranger field, from the Black Lime. The sand was encountered at about 2,685 feet. The other wells of about the same size have been completed very near the Duke well but the results of wells at some distance to the south from the first well have been disappointing. To the northward the development has proceeded rapidly and the center of the activity is now (Aug. 1, 1919), around the village of Desdemona in Eastland county.

The only other locality in Comanche county in which oil or gas has been found is west of Sipe Springs where a well is reported to be making some oil and gas, with sulphur water.

The approximate locations of other deep tests and their depths on April 1st, 1919, are shown on the accompanying map (fig. 88.).

At the end of March, 1919, the reports from Comanche county show 2 wells producing 25 barrels each per day; 4 wells producing between 400 barrels and 650 barrels per day and one well producing 2,800 barrels per day; making a total of 7 wells with a total average daily production of 4,985 barrels.

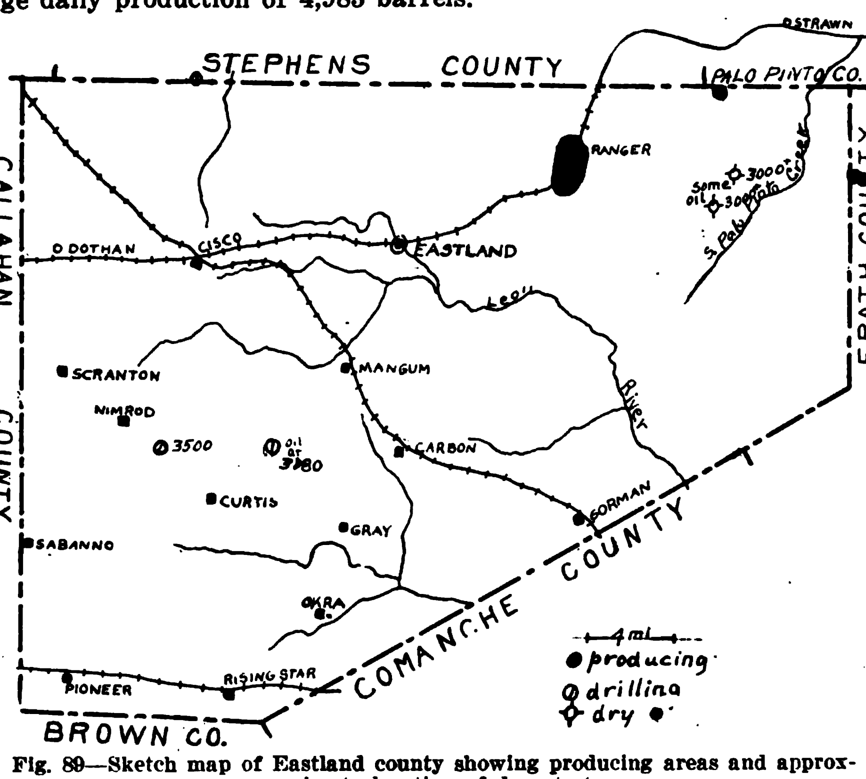


Fig. 89—Sketch map of Eastland county showing producing areas and approximate location of deep tests.

Eastland County.

The surface rocks of the greater part of Eastland county are Pennsylvanian in age, the Strawn, Canyon and Cisco formations all covering considerable areas. The southern and part of the eastern portions of the county are covered with sand of the Trinity formation of the Comanchean system. The general dip of the Pennsylvanian rocks is to the northwest as in the rest of the area, but small variations from the normal dip are common and there is some minor faulting. In the eastern part of the county there is at least one large fold with rather steep dips and considerable closure. The structure of the Pennsylvanian rocks in the areas covered by Trinity cannot be determined.

The most important development in Eastland county as well as in this part of Texas is the Ranger field. The discovery well in this field was completed in the summer of 1917 and the development has been extremely rapid and a typical "oil boom" has taken place at Ranger. However, on account of the greater cost of drilling and the fact that most of the territory was controlled by one company there has been no such inflation of lease prices nor such an orgy of speculation and small company promotion schemes as there has been at Burkburnett.

The rapidity of the development is shown by the following statistics from the Oil and Gas Journal.

At the end of 1917 only five standard rigs were reported as in Eastland county. By the end of 1918 there were 47 producing wells, 33 wells shut down on top of the sand, 29 dry holes and gas wells, 185 wells drilling, 120 rigs waiting for machinery and more than 100 locations. This activity is practically all in or near the Ranger field.

On account of the great importance of this field the following description is given in full.

THE RANGER OIL AND GAS FIELD

(By F. W. REEVES AND W. C. BEAN.)

The Ranger oil and gas field is located in the northeast corner of Eastland county, Texas, and derives its name from the town of Ranger which is situated near the center of the field.

At the present stage of development it is impossible to state the limits of the field. It is about eight miles from the Brashear well on the south to the Whitson and Williams wells on the north and five miles from the Davis and W. L. McCleskey wells on the east to the Roper well on the west. Within these limits few dry holes have been drilled up to the present time, but further development may disclose more barren areas or greatly extend the limits of the field.

The credit for the discovery of oil at Ranger belongs to the

Texas and Pacific Coal company. The business men of Ranger county and arrangements were made with the Texas and Pacific leased a large block of acreage in the northeast part of Eastland Coal company to test it out. A number of wells were drilled in the vicinity but it was not until October, 1917, that oil was found in paying quantities. In the latter part of that month the J. H. McCleskey No. 1, the discovery well, first struck the pay horizon and began making 400 to 500 barrels per day. In the early part of November the well was drilled several feet deeper into the sand and the flow increased to 1,400 barrels.

At the time of discovery of oil at Ranger the Texas and Pacific Coal company held under lease nearly all the land now covered by the field. However, since then this company has sold some of their acreage or made drilling agreements with other companies who are carrying on the development. At present the Prairie Oil and Gas company, the Texas Company, the Gulf Production company, the Magnolia Petroleum company, the Humble Oil & Refining company, besides numerous small companies and individuals have production in the field. The development of the field since the J. H. McCleskey No. 1 was drilled in has been very rapid in spite of the difficulties in obtaining supplies, labor and water, during the first year of the field's development.

The rocks exposed at the surface in the Ranger field consist of limestones, sandstones, and shales of the Canyon series of the Pennsylvanian system. The most prominent member of the series is a dark gray limestone about 35 to 40 feet thick which forms an escarpment just west of the town of Ranger. Below this heavy limestone occurs a series of shales and thin sandstones 40 to 50 feet in thickness, at the base of which is a thin brown limestone which outcrops diagonally across the town of Ranger.

A generalized section taken from well logs shows that the drills penetrate approximately 500 to 700 feet of alternating limestones and shales belonging to the Canyon series, 2,000 to 2,200 feet of sandstones and shales interbedded with thin limestones belonging to the Strawn series and about 1,100 feet of black shales and limestones belonging to the Bend series. The entire thickness of the Bend series is penetrated in only a few of the wells as the productive horizons are found near the top of the black limestone. The upper 400 to 500 feet of the Bend series consists mostly of black shales which may be correlated with the Smithwick shales outcropping in San Saba and Llano counties. Below these shales are approximately 500 feet of gray and black limestone interbedded with thin shales, making up the Marble Falls limestone. Below the limestone is 100 to 125 feet of black shale which may probably be correlated with the Lower Bend shale which outcrops in San Saba county. A few of the deeper wells penetrate a compact white limestone

at a depth of 3,600 to 3,800 feet. This is probably the Ellenburger limestone of Cambro-Ordovician age.

The structure as shown by the dip of the rocks exposed at the surface consists of a series of plunging folds or anticlines. The largest of these plunges northwestward from the neighborhood of the Walker well No. 1, where the beds are flat. This fold is flanked on either side by minor folds which also plunge northwestward. The minor fold on the northeast starts in the vicinity of the Hagerman well No. 1, while the one on the southwest begins near the J. H. McCleskey well No. 1. Another minor fold is found in the south-central part of the field in the vicinity of the Floyd Brewer wells. Structure contours on rocks exposed at the surface show no closures in any part of the field.

The structural conditions of the Bend series, in which the production is found, varies considerably from the surface structure due to the marked unconformity between the Strawn and Bend series. The most important structural feature of the Bend series as shown by a study of well logs available at the present time is a large dome which extends from the C. J. Keaghy well No. 1 and T. W. Duncan well No. 1, on the south, to the W. E. Jones No. 2 and Magnolia Petroleum company Rock No. 1, on the north. Plunging anticlines extend from this dome northwestward through the Emma Terrell No. 1 and westward through the Butler No. 1. Between these two anticlines is a small syncline.

The main structure is flanked on the southeast and northeast by two smaller anticlines. The one on the southeast has its crest in the vicinity of the Brewer wells and plunges northwest. The one to the northeast is located in the neighborhood of the Walker No. 1, but its extent is as yet not well defined.

A structural basin extends south from the town of Ranger through the Yandell No. 1, Meyers No. 1 and Pitcock No. 1 and then turns eastward. Other small synclines appear in the vicinity of the J. T. Falls No. 1 and J. M. Rush No. 1.

The subsurface structural features cannot be more definitely defined until more well logs are available. It seems that the structural conditions of the Bend series are reflected to some extent in the surface structure but in a modified form due to the unconformities between the Canyon and Strawn series and between the Strawn and Bend series.

At the present time the production in the Ranger field is practically confined to two horizons, the deeper of which is the more productive. This deeper sand is encountered at depths ranging from 3,200 to 3,500 feet, depending upon the elevation of the ground at the well and the position of the well in relation to subsurface structure. The maximum thickness of this sand which has been reported at this time is about 30 feet. On the other hand, the logs

of some of the dry holes do not show any sand at all, while others indicate a sandy lime at this horizon. It is possible, therefore, that in places the sand pinches out entirely within a short distance of production.

Some oil as well as gas is obtained in some of the wells at a horizon about 175 to 250 feet above the main pay. This production is usually reported in lime or sandy lime though in a few cases the formation is classed as sand. Both these productive horizons are included in that part of the geologic section which has been correlated as Marble Falls limestone belonging to the Bend series.

A few wells within a limited area at the southwest edge of the field are producing from a pay which was first struck in the J. E. Crosby No. 1 at a depth of 1,340 feet. This productive sand, which is about 30 feet in thickness where first encountered, is a member of the Strawn series.

There are now (Mar. 15, 1919) nearly 100 wells producing oil in the Ranger field and the number is increasing rapidly. A number of wells in the field have an initial production as high as 1,000 to 4,000 barrels and the initial production of the Emma Terrel No. 1 is reported as 8,000 barrels. The best production at present is from the area one to three miles west of Ranger and in the neighborhood of the Brewer group three to four miles south of Ranger.

A number of gas wells are scattered in various parts of the field and some of these produce a large volume of gas. A number of wells which produced only gas when first brought in are now making considerable oil. All the oil wells have enough gas pressure to make natural flow. The gas is used as fuel in drilling and a small amount is distributed for consumption in the town of Ranger.

The oil produced in the Ranger field ranges from 36 degrees Baume to 42 degrees Baume.

The production of the field is curtailed at the present time by lack of storage and transportation facilities for handling the oil. Many of the wells are shut down at the top of the sand waiting for storage. On Jan. 1, 1919, there were more than two and one-half million barrels of oil in stock near Ranger. During December, 1918, about 235,000 barrels of crude oil were shipped out of Ranger in tank cars.

The Texas Company has recently completed an 8-inch pipe line from Ranger to Fort Worth and the Prairie Pipe Line company has an 8-inch to Pauls Valley, Okla. A number of other pipe lines from Ranger are now under construction, among them a 12-inch line to Pelican Island, another to Corsicana and a second line to Fort Worth. Twenty storage tanks, having a total capacity of 352,500 barrels are now at various stages of construction near Ranger.

The development of the Ranger field to March 15, 1919, is shown in fig. 90.

* * * * * * * * * *

Outside the Ranger field there has been little important development in Eastland county. The northward extension of the Duke pool of Comanche county lies in Eastland, but the pool is discussed in connection with Comanche county. In the northeastern part of the county, about 12 miles south of Strawn, two wells have been drilled at the west end of a large structure. Both had some oil and gas, but no production has resulted. A well about 3 miles south of Eastland was good for about 5 barrels at over 3,000 feet. South-

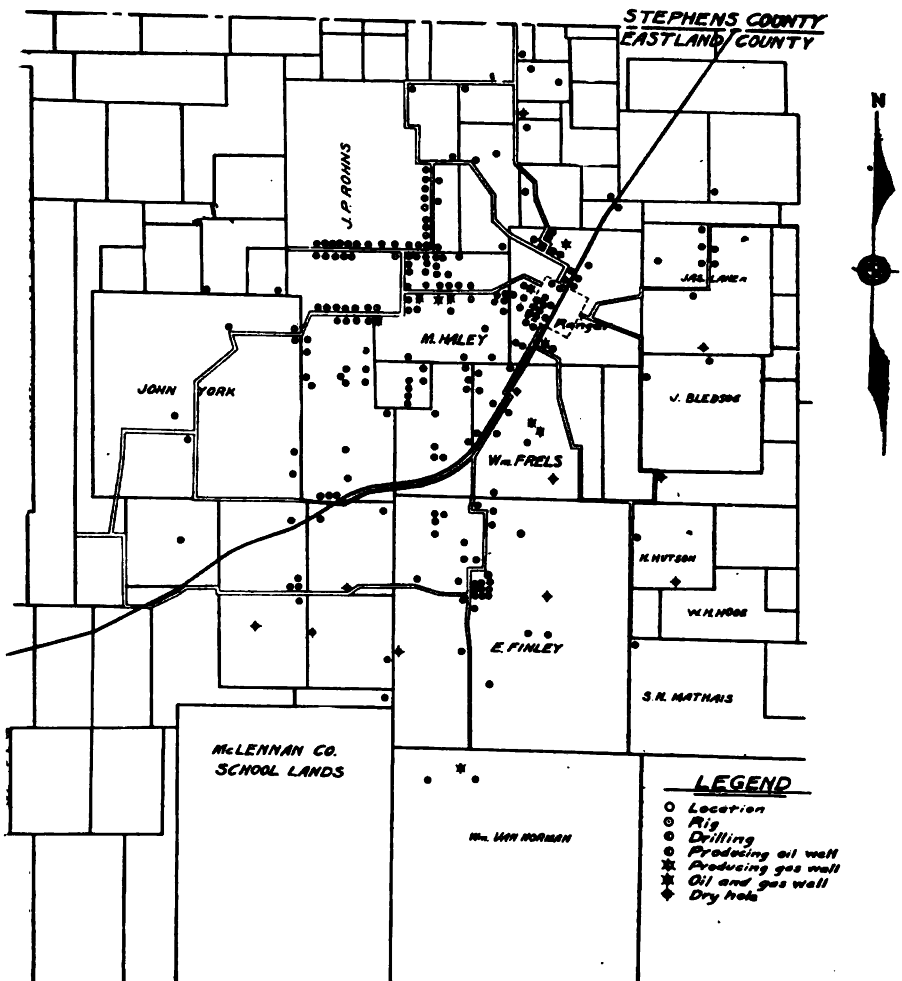


Fig. 90—Map showing development of the Ranger field.

west of Cisco about 10 miles a well is dry at 3,500 feet. The location of the Ranger field and of the important deep tests outside this field is shown in fig. 90.

At the end of March, 1919, the reports from Eastland county showed producing wells as follows:

40 wells producing less than 25 barrels per day,
22 wells producing between 25 barrels and 100 barrels per day,
53 wells producing between 100 to 500 barrels per day,
18 wells producing between 500 and 1,000 barrels per day,
19 wells producing over 1,000 barrels per day,

making a total of 152 producing wells with a total daily production of 70,742 barrels. The total initial production of these wells was 130,617 barrels per day.

Brown County.

Brown county lies to the west of Comanche and south of Eastland. Considerable areas in the eastern and southeastern portions of the county are covered with the Trinity division of the Comanchean but the greater part is occupied by the outcrops of the Strawn and Canyon formations of the Pennsylvanian. The normal structure is a nearly west dip of about 60 feet to the mile and there are very few pronounced variations from this dip.

The principal development has been a shallow sand found in the immediate vicinity of Brownwood. This pool was developed in 1917 and was quite active during the first half of 1918, when new development practically came to a standstill. The field occupies an area of about 4 square miles, in the southwestern part of Brownwood and the adjacent country. The sand lies at depths varying from 150 to 350 feet, the depth increasing to the west, both on account of the dip of the sand and the elevation of the surface. The sand varies in thickness from 2 to 40 feet. Ordinary water-well drilling machines were used, and the wells pumped by means of small gasoline farm engines. Three or four days were required to finish a well. Some of the wells were not cased while others were cased with galvanized water-well casing. In some wells the ordinary 5 5-8 inch casing was used. The initial production, while only a few barrels per well per day was very satisfactory for such shallow drilling and the wells paid out very rapidly. Some of the deeper wells had a production of as much as 100 barrels per day. The oil is of good grade. Two small refineries have been built at Brownwood but most of the production was shipped to other refineries in tank cars. The wells are very closely spaced. The daily production is reported (April 25, 1919) as 675 barrels.

The deep drilling in Brown county, so far, has not been productive of important results, but sufficient showings and small wells have been found to make the territory look promising.

Some two or three years ago, considerable flows of gas were found in wells northwest of Bangs at a depth of about 1,600 feet.

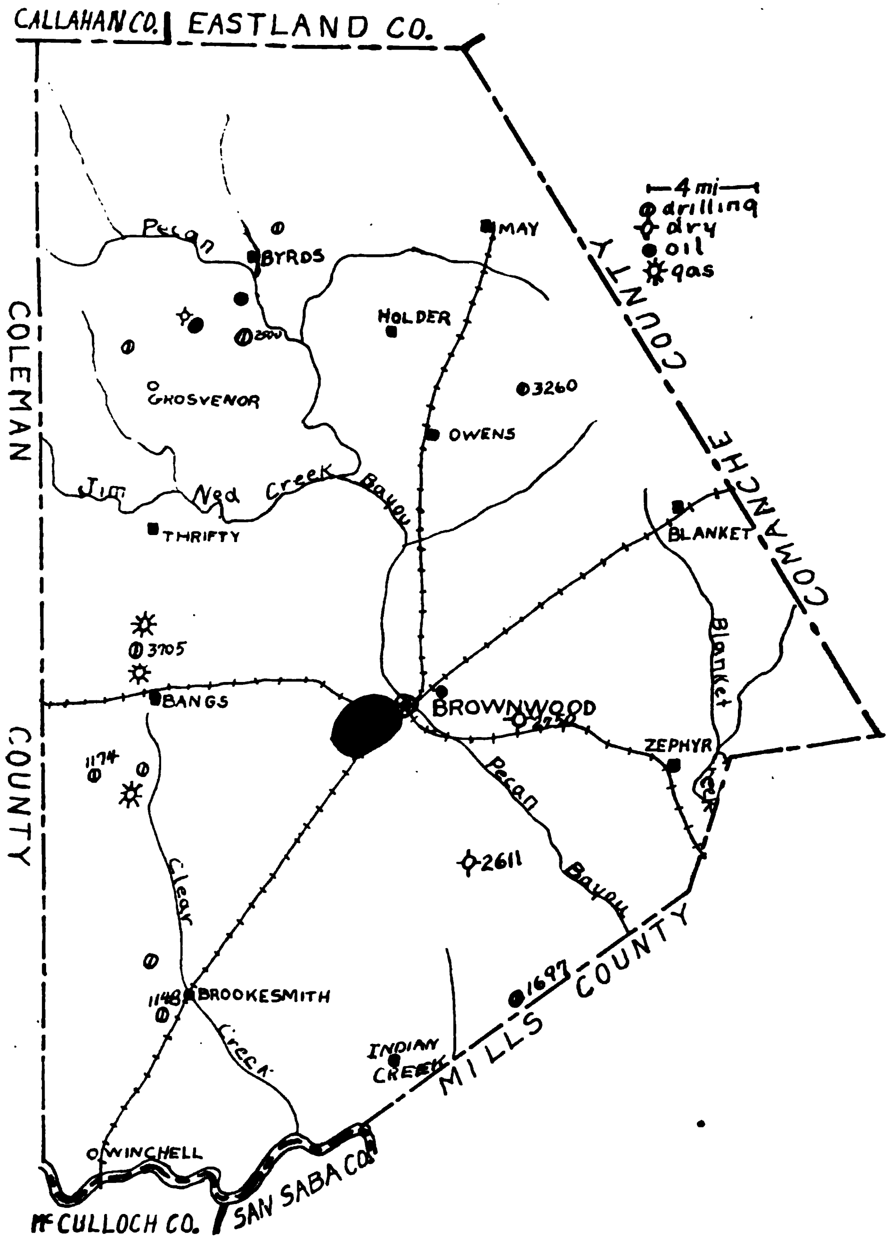


Fig. 91—Sketch map of Brown county showing producing area and approximate location of deep tests.

The gas is piped to Bangs. A well near the gas wells has been carried to a depth of 3,700 feet with only small showings.

The Sinclair Gulf well near Byrd's in the north part of the county is a small well with the production from the Black Lime. The Bayley well about 3 miles to the southwest is also a small producer. The depth to production in these wells is practically the same. The well on the Weedon farm south of the Sinclair and east of the Bayley well is reported dry after a shot in the Black Lime between 2,000 and 2,500 feet. A well near Grosvenor was dry at over 3,100 feet. A well six miles east of south of Brownwood was dry at 2,600 feet, and one four mles east of Brownwood at 2,750 feet.

Other wells drilling at considerable depths are: a well about 8 miles east of north from Brownwood and a well near Cleo in the northeastern part of the county, both shut down at or near 3,200 feet. Ten other wild cat wells are reported as being drilled in the county.

In April, 1919, the Capps well, 2 miles east of Brownwood was reported to be showing for a producing well. The location of the shallow production at Brownwood and of the deep tests drilled in Brown county are shown in fig. 91.

Coleman County.

The eastern part of Coleman county is underlain by the Cisco formation and most of the central and western parts by the Albany facies of the Wichita formation. Some outliers of the Comanchean cover considerable areas. The most conspicuous of these outliers are the hills near Santa Anna, known as the Santa Anna mountains. The normal structure in the Pennsylvanian and Permian rocks is a west dip of about 60 feet to the mile and this dip is very uniform. The Strawn formation which has a thickness of 3,000 feet or more at its outcrop thins rapidly as it passes westward under Brown and Coleman countes so that the Black Lime of the Bend series is much nearer the surface than was at first thought. The Strawn seems to be absent along the west line of Coleman county as a well drilled south of Talpa passed directly from the white limestones and the shales of the Canyon formation directly into the Bend series.

So far the development in Coleman county has given several small wells of both oil and gas, but these discoveries have not resulted in the opening of any important pools. In every case the productive areas have been proven to be small and the wells of small size. Early in April, 1919, the daily production of the county was reported* as being only 195 barrels.

The principal developments are in the eastern half of the county, the Morris and Mitchell pools in the northeastern part, the

*Oil and Gas Journal.

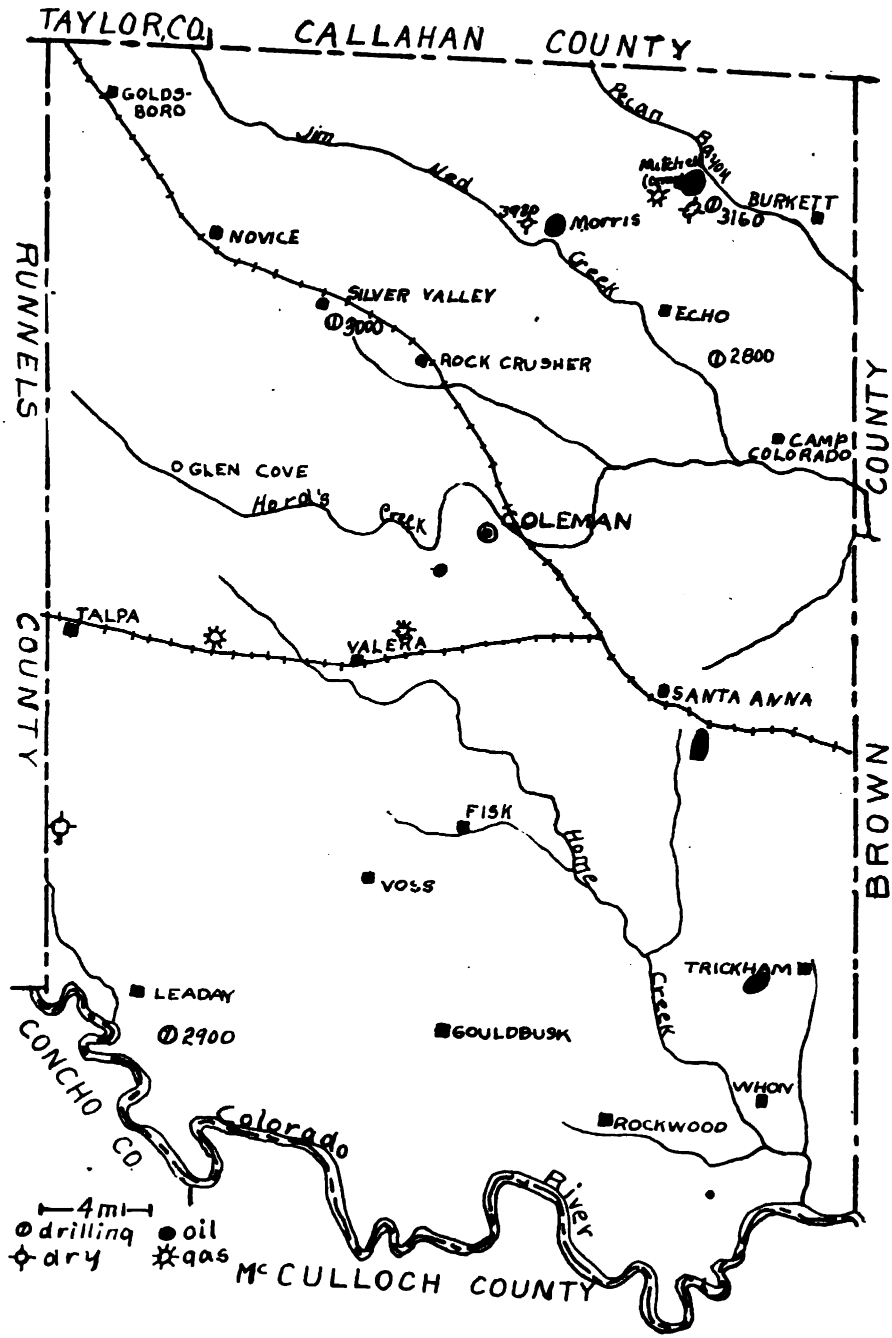


Fig. 92—Sketch map of Coleman county showing location of producing areas.

Santa Anna pool in the east central part and the Trickham pool in the southeastern part.

The Morris pool, named from the Morris ranch, has about 4 small producing oil wells and a deep dry hole just west of the development. The sand was missed in this well so the area seems limited on the west. The producing sand is encountered at about 2,500 feet.

The Mitchell pool is located about 6 miles northeast of the Morris pool. The wells are small and the area is limited by dry holes to the north and east. Only three or four wells are producing. The producing horizon is in the Black Lime.

About 2 miles southeast of Santa Anna and in an area about 2 miles west of Trickham there have been several small oil and gas wells drilled. This production is from above the Black Lime, probably in the Strawn formation. The production is not very important at present, but gives intersecting possibilities. Small gas wells have been drilled near Valera and Talpa.

The location of the producing area is shown in fig. 92.

McCulloch County.

In the latter part of 1918, a small pool was developed a few miles north of Brady, at a depth of about 300 feet. The wells early in 1919 were making less than a barrel per well per day and the discovery does not appear to be of commercial importance. Several deep tests have been unsuccessful.

CRETACEOUS AREA.

The principal fields of the Cretaceous area are the Corsicana oil and gas field and the Mexia-Groesbeck gas field. There are several minor occurrences.

*Corsicana Oil and Gas Field**

The Corsicana oil and gas field is situated in Navarro county, Texas, extending from Corsicana eastward to Powell, and from the vicinity of Angus northward to Chatfield. The boundaries of the field include about 200 square miles, but of this area only about 50 square miles is productive. The field is divided into two parts—the Corsicana district, immediately east of Corsicana, and the Powell district, including a number of small pools near Powell and Mildred.

The producing areas are shown in fig. 93.

The surface of the Corsicana field is part of the Black Prairie

*Matson, G. C., and Hopkins, O. B., The Corsicana Oil and Gas Field, Texas; Bull. U. S. Geol. Survey No. 661, pp. 211-252, 1917.

and there is a thick mantle or residual soil obscuring all outcrops so that the determination of geological conditions rests almost entirely on the interpretation of well logs.

The rocks penetrated by the drill in the field are as follows:

Eocene—

Midway formation, outcrops in eastern part of the field marl with thin beds of limestone.

Cretaceous—

Navarro formation, consists of gray, greenish-gray and yellow, nodular calcareous clay and sandy clay and fine, glanconitic, calcareous sand, contains the Nacatoch sand, which is thought to be the oil-bearing sand in the Powell district at Corsicana, is about 400 feet thick.

Taylor marl, consists of uniform series of light to dark gray fine-grained highly calcareous clay or clay marl—about 1,000 feet thick, some sandy beds of which one in the upper part is the oil producing sand in the Corsicana field.

Austin chalk, alternating beds of white to light gray chalk and marl of varying degrees of hardness, 425 feet thick.

Eagle Ford shale, gray to dark-colored fine-grained clay and thin layers, and probably concretions of limestones, 376 feet thick. Farther northeast the Eagle Ford contains the Blossom sand member which is productive of oil and gas in the Caddo pool, but this member does not seem to be present in the Corsicana field.

Woodbine sand, consists of sandstone and sandy clays with some beds of hard sandstone, at Corsicana it has been penetrated to a depth of 400 feet but not drilled through.

The oil from the Corsicana district is a light oil, showing a gravity of 38 to 59 degrees Baume, with about 20 per cent of gasoline; that from the Powell district is a heavy oil with a gravity of 20 to 30 degrees Baume and from 1 or 2 to 10 per cent gasoline. The base of oil is principally paraffin, but nearly all of it shows a small percentage of asphalt. The unsaturated hydrocarbons are high, from 8 or 10 to about 30 per cent.

The wells in the entire field have been small producers; initial production of over 200 barrels per day have been reported but the majority of the wells started at less than 50 barrels per day. The wells decline rather rapidly for a few months and then continue producing at nearly uniform rate for many years unless invaded by salt water. Some wells have been producing for nearly 20 years. The average life is 9 or 10 years. The ultimate production is estimated at 1,948 barrels per acre. The production is probably governed by the character of the sands which are fine-grained and fairly compact.

Drilling is done with rotary rigs and the cost of drilling is low. The cost of wells, exclusive of casing is about $550 to $650 in the

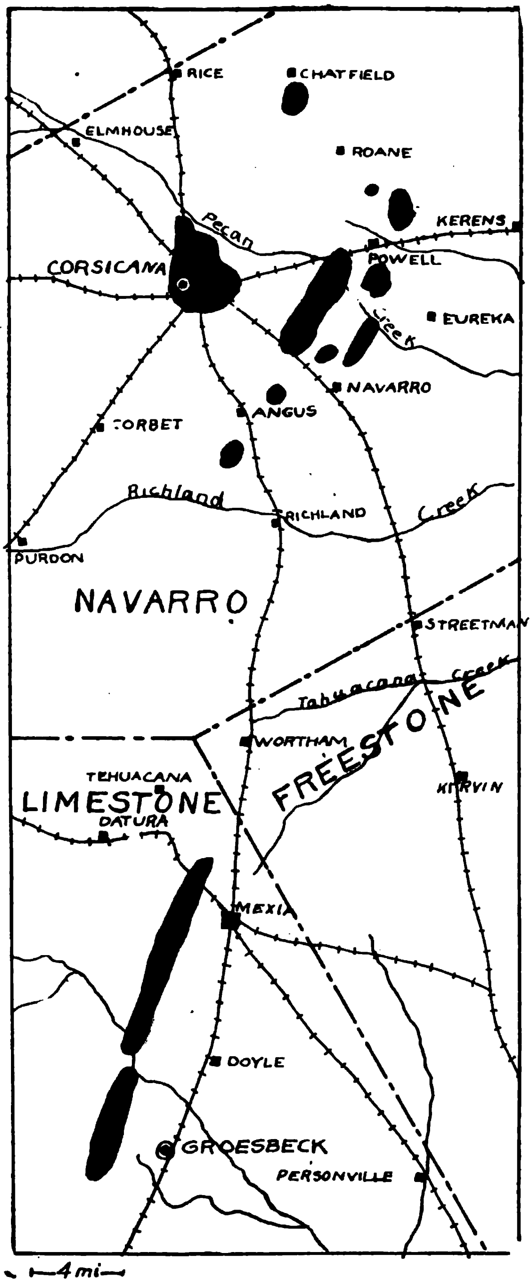


Fig. 93—Map showing producing areas in the Corsicana and Mexia-Groesbeck fields.

Corsicana district and $350 to $450 in the Powell district. Three to ten days are required to drill a well in the Corsicana district and from two days to a week in the Powell district. Water is troublesome only around the edges of the pool. The wells are drilled into the sand from 25 to 60 feet. Gas occurs in small areas near the western side of the pool where the beds are highest. The Edens sand is about 300 feet above the Corsicana sand. This sand produced considerable gas in the Edens pool, but the wells were soon exhausted and the wells abandoned. The gas sand in the Chatfield pool is believed to be the Edens. The wells in this pool were also short lived and were abandoned several years ago. The sands in the Angus pool occur in an interval of about 150 feet and are believed to represent the Nacatoch sand although they may be equivalent to the Corsicana sand.

In the Powell district as many as four productive sands are

present. These all occur within an interval of about 100 feet, which is believed to represent the Nacatoch sand. They are about 800 feet above the Corsicana sand and the top of the series is at a depth of 650 to 900 feet. In some parts of the Mildred pool all four sands are present and most of the wells are drilled into the deepest sand with the casings set at the top of the highest sand. In the Witherspoon-McKie pool the upper and lower sands are productive. In the Clements-Buchanan pool only the upper, and in the Burke-Combest, and White pools only the lower sand is productive.

The structure of the main Corsicana pool is monoclinal. The dip is to the southeast and there are some variations in the rate of dip, but none of great importance. The data on the Edens pool are not conclusive, but indicate a low anticline. The gas accumulation at Chatfield is on a low, irregular anticline. The Mildred pool is on an irregular anticline. The production follows the structure in a general way but not in detail. The Witherspoon-McKie pool is on the crest of a low flat-topped anticline. The Clements-Buchanan pool is on an accentuated normal dip, as is also the case with the Tilton-Havener and Angus pools. The Burke pool is on a well-defined anticline.

In the Corsicana district, there are two productive sands, the Corsicana and Edens, which are believed to lie in the Taylor marl. The Corsicana sand is the principal producing sand, yielding light oil and gas. The Edens sand yielded gas in a small area southeast of Corsicana. The Corsicana sand is from 900 feet to 1,200 feet below the surface in the Corsicana pool and ranges from a few feet to 60 feet in thickness. The wells are pumped by centrally-located power plants, operating sucker-rods attached to pumping jacks at the wells. Fifteen to twenty-five wells may be pumped by one power. Casinghead gas is utilized for fuel. The wells in the Powell district require cleaning-out at frequent intervals. The gas wells of the field have been, in general, very short lived.

The Corsicana field was discovered in 1895 and for six years was the only important producer of oil in Texas. The Powell district was opened in 1900. The features of the field as they stand today, have been defined for several years and there seems to be little chance of important extension of productive area of the field. There is, however, possibility of production from deeper sands, especially in the Powell district where the Corsicana sand has not been well tested in favorable localities.

The average price for the oils from the field from 1913 to 1916 is as follows:

Average Price of Oil Per Barrel in Corsicana Field 1913-1916.

	1913	1914	1915	1916
Corsicana district	$0.987	$0.923	$0.744	$1.242
Powell district	.766	.600	.449	.631

*The Mexia-Groesbeck Gas Field**

The Mexia-Groesbeck gas field is in the east-central part of Limestone county. It extends southward from near Mexia in a narrow belt, to a point a short distance southwest of Groesbeck. The total length of the field is about 12½ miles and the width a little less than one mile.

The field has the same general geologic conditions as has the Corsicana field just described. The wells start in the Midway (Eocene) formation and encounter the gas in a sand in the Navarro formation, which is considered to be the Nacatoch sand member. The depths vary from 670 to 900 feet, the majority of them being near 700 feet. The thickness of the sand is about 40 feet. The sand consists of quartz grains partially cemented by glanconitic. It is quite porous, showing an average pore space of 25.5 per cent. The slight variation in rock pressure and the uniform rate of decline of pressure indicate fairly uniform porosity in the sand.

The structure of the field is a long, well-defined anticline with at least 150 feet of reverse (northwest) dip which is much steeper than the southeast or normal dip. Well logs must be used to determine the structure and the whole anticline cannot be delineated.

The first successful well was drilled in 1912. Previous to its bringing in, twelve unsuccessful wells had been drilled. Fifteen or sixteen wells were added in 1913 and about 30 in 1914. At the end of 1915, there were 46 and at the end of 1916 there were 53 productive gas wells in the field. Several wells have been abandoned which could probably be rejuvenated by proper methods. The average closed pressures at the ends of the years since the field was opened are as follows: 1912, 275 pounds; 1913, 273 pounds; 1914, 240 pounds; 1915, 200 pounds; and 1916, 180 pounds. The open flow volume of the field at the end of 1915 was about 220,000,000 cubic feet per day, and the total quantity of gas in the field at that time was estimated at 2,331,057,000. No oil has been found in the field and the gas is dry, consisting almost entirely (over 98 per cent) of marsh gas. The gas is supplied to Mexia, Groesbeck, Waco Mart, Corsicana and some smaller towns.

*The Thrall Oil Field**

The Thrall oil field is located one mile southeast of Thrall, in southeastern Williamson county. The surface is gently undulating with a thick mantle of black soil.

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*Matson, G. C., Gas prospects south and southeast of Dallas; Bull. U. S. Geol.
*Udden, J. A., and Bybee, H. P., The Thrall Oil fields, Bull. Univ. of Texas, No. 66. 1916.

Oil was discovered at about 300 feet in 1914 in an attempt to obtain water. The showings were sufficient to lead to deeper drilling and the first commercial well was completed early in 1915.

The rocks penetrated by the drill are the Taylor marl, Austin chalk and Eagle Ford shale of the Cretaceous. The Buda limestone of the Comanchean is reached in one or two of the deeper wells. Only a few wells went deeper than the oil horizon in the Taylor marl.

The oil producing horizon is unique in that it is an altered igneous rock. The rock was originally a basalt or similar rock which has been altered into a porous serpentine. The rock may be an intrusion of later date than the Taylor marls but is regarded as being more probably a contemporaneous extrusion on the sea bottom. The cuttings from the rocks next to the igneous mass do not shown signs of the metamorphism which would be expected if the body were intrusive.

The Serpentine forms an irregular dome-shaped mass, thickest near the center, where a thickness of over 500 feet is shown in a well log, and thinning in all directions. The upper surface slopes most rapidly to the south, and most gradually to the north. The greatest known diameter of the mass is about 5,000 feet in a north-south direction, and the east-west diameter is about 4,800 feet. The thin edges of the igneous mass probably extend beyond these distances. The depth of the igneous rock below the surface varies from about 600 to about 900 feet.

The oil is found both in the serpentine and in a porous shell breccia which is contiguous to the serpentine.

The high porosity of the containing rocks gave wells of large initial capacity and was also responsible for an extremely rapid decline.

Of 105 wells drilled previous to November, 1916, 7 were dry; 26 had initial productions of less than 40 barrels, 22 of between 40, and 200 barrels, 15 of between 200 and 1,000 barrels, and 7 of between 1,000 and 5,000 barrels. Within about 6 months after the field was opened the average production was less than 10 per cent of the initial production and within 16 months only 8 of 138 wells were making more than 26 barrels per day and 96 were making less than 6 barrels.

The total production to November 4, 1916, was approximately 1,500,000 barrels. The crest of the production was reached in May, 1915, when over 200,000 barrels were produced. By October, 1916, the monthly production had declined to about 24,000 barrels, and the decline has continued since that time until the production is quite small. The oil from the Thrall field is reddish in color, and has a gravity of about 40 degrees Baume. The base is paraffin and

considerable ozocerite separates in the tubing and pipes making it necessary to clean them at frequent intervals.

Minor Occurrences in the Cretaceous Area.

There is a small gas field, near Crowther in McMullen county. in 1916 six wells were supplying Crowther with gas and 10 were not being used. There is also a small amount of light oil.

In northern Zapata county, a small gas field was discovered on the Jennings ranch, in a well drilled for water. The well had a capacity of 15,000,000 cubic feet of gas per day at a depth of 1,314 feet. Other wells were drilled and the gas piped to Laredo, 30 miles to the northwest, in 1916. Further development has failed to enlarge the area and the producing company has recently gotten a supply of gas a short distance east of Laredo.

A well producing 5 to 8 barrels per day on the pump was drilled south of Brenham in Washington county in 1915. The depth was 1,340 to 1,420 feet. Additional development has been without results.

Some shallow oil has been known for several years near Piedras Pintas in Duval county. Deep tests have been started but no completions have been made.

Some small development of oil has taken place in Bexar county near San Antonio. The Alta Vista and Van Petty pools lie respectively 8 and 10 miles south of San Antonio. Both are shallow and the wells are only small producers. The oil in the Van Petty pool is of about 36 degrees Baume gravity, but that of the Alta Vista pool is heavier. The development can scarcely be said to be important at present, but may lead to more of value.

OIL AND GAS FIELDS OF NORTHWEST LOUISIANA.

The oil and gas fields of Louisiana which are considered as belonging to the Mid-Continent fields are located in the extreme northwestern part of the state, in Caddo, De Soto, and Red River parishes, and are grouped into two fields or districts, the Caddo and the De Soto-Red River.

The surface rocks in all this portion of Louisiana, are Eocene clays and sands. The rocks are very soft and the bedding irregular so that exposures are very few and short. The only geologic work which can be done in advance of drilling is the measuring and plotting of the dips, and these are not very reliable.

The rocks in the general district have a slight dip toward the south, but in the productive areas this dip is affected by a large uplift known as the Sabine uplift, which brings the Cretaceous rocks within 700 feet or less of the surface over a considerable area

The Sabine uplift is not a simple fold, but a large anticline with many minor folds and wrinkles superimposed upon it. In general, the accumulation follows the structure very closely and even the minor flexures seem to have a pronounced effect on the distribution of oil and gas and on the size of the wells.

In all the area production is from sand members in the Cretaceous system, which has been rather fully described for the adjoining territory in Texas. The productive horizons are named in the discussions on the fields.

Caddo field—The Caddo field is located in the western part of Caddo Parish and extend westward across the state line a short distance into Marion county, Texas. The principal part of the field extends from Mooringsport northwestward for about 12 miles and has an extension reaching about 10 miles northeast from the main part of the field. The largest wells are in a rather narrow belt, northwestward from Mooringsport. The productive areas are shown in fig. 94.

The field is divided into seven districts or pools that merge more or less closely into each other.

The productive horizons are four in number—

The Nacatoch sand is the most important gas sand in the field and has produced some low-grade oil. It consists of alternations of hard and soft layers which are not continuous over large areas. The total thickness of the sandy horizon varies from 50 to 150 feet. The oil and gas occur in the upper part of the formation and the lower is filled with salt water in most places.

The Annona chalk has supplied large quantities of low-grade oil to a few wells. On account of the small areas of the production it is supposed to come from fissures or crevices.

The Blossom sand or 1,800-foot sand gives strong flows of gas from its upper portion, but care is necessary to keep from drilling into the salt water which underlies the gas.

The Woodbine sand is the great producer of high-grade oil in the field and also gives considerable gas locally. The gas has the odor of petroleum and is suitable for the manufacture of gasoline. There seem to be two productive horizons, one lying from 225 to 275 feet below the top of the Blossom sand and the other about 100 feet lower.

There is considerable variation in the intervals between the different sands and they are not parallel throughout the field in general, the deeper sands show the steeper dips and the more complex folding.

The oil wells of the Caddo field have a strong gas pressure and most of them come in as gushers. The decline is very rapid as the gas pressure is relieved. Wells of 5,000 to 10,000 barrels have not

been uncommon, although the majority have much smaller initial productions. Owing to the intimate association of the oil with salt water, many wells have passed directly from the gusher class into

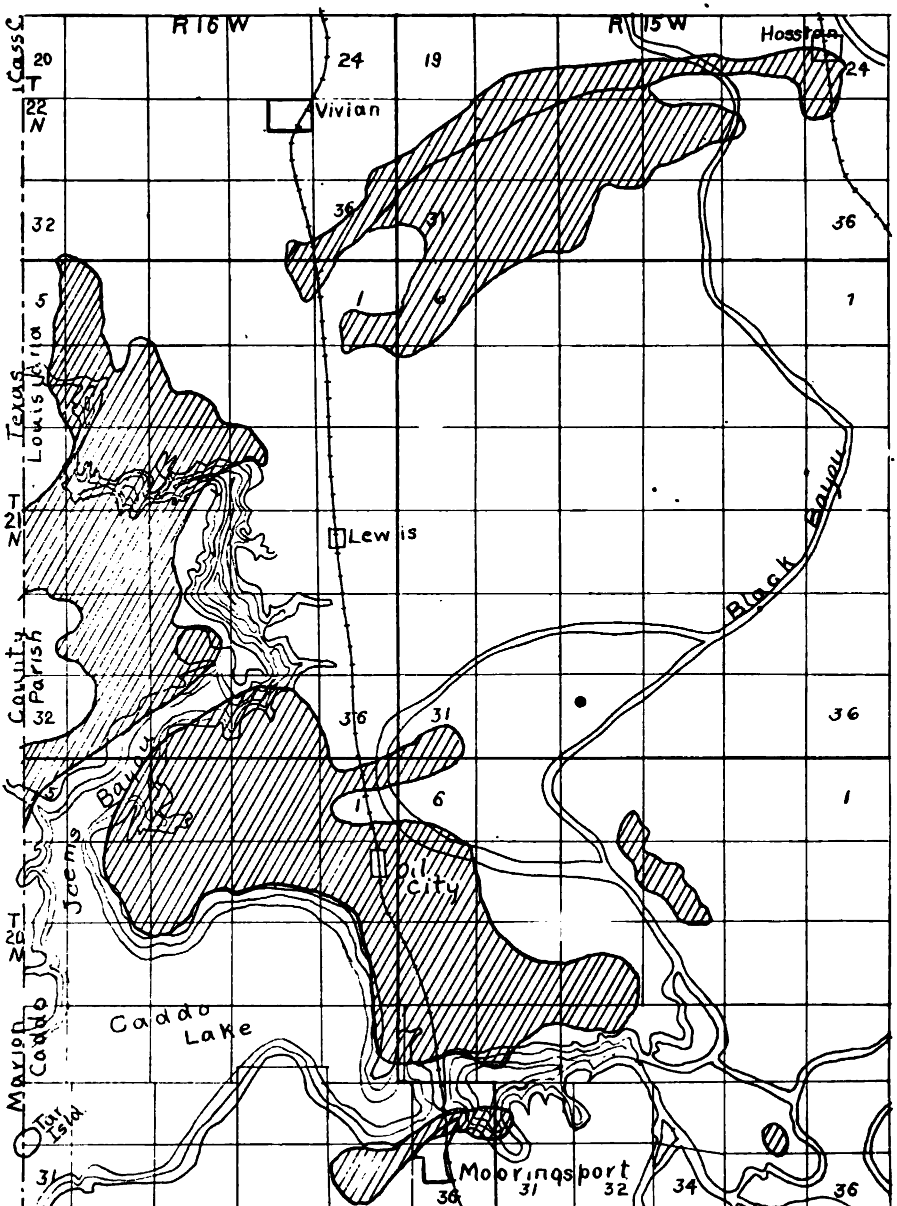

Fig. 94.—Map showing the productive areas of the Caddo oil and gas field.

producers of large volumes of water. The gas wells are very large volumes, up to 50,000,000 cubic feet or more, and have tremendous pressures. On account of the unconsolidated nature of the rocks and the absence of satisfactory beds on which to land and set casing, many wells have broken loose and run wild for months or even for years before they could be controlled.

The oil of the Caddo field varies greatly in quality ranging from 19 degrees to 45.5 degrees Baume. The oil is classified as light and heavy, the separatian being at 38 degrees Baume. The prices for the two classes vary considerably.

During 1917 and 1918 the greatest activity in the Caddo district is in the Pine Island pool in the eastern part of Caddo Parish. Wells of very large size have been brought in but the oil is of low grade.

The statistics given for North Louisiana in the tables at the end of the section on the History of the fields are practically those for the Caddo field except for the last two or three years during which they are affected by the De Sota-Red River field.

*De Soto-Red River field**—The De Soto-Red River oil and gas field takes its name from the parishes in which it is located.

The production is scattered over Tps. 12 and 13 N, Rs. 10, 11, 12 and 13 W. The center of the field is about 30 miles southeast of Shreveport. The field extends from Naborton northeastward across Red river to Crichton.

Gas was discovered near Naborton in 1912 in a sand at about 800 feet. Oil was discovered by deeper drilling early in 1913. The Abington district in Red River parish was opened in April, 1914, and the Crichton pool in November, 1914.

The stratigraphy of the region is practically the same as that of the Caddo field. The surface rocks belong to the Wilcox formation of the Eocene, and the Recent deposits of Bayou Pierre and Red river valleys. About half the territory is covered by the Recent deposits and has no outcrops. The east and west ends of the territory lie in the hilly country where short outcrops make it possible to determine something as to surface structure.

The rocks of the Cretaceous system are reached by the drill at a depth of a few hundred feet and all the productive sands are within this system.

The productive sands are as follows:

The Nacatoch sand is encountered at depths of from 725 to 950 feet depending on the surface elevation and the position on the structure. It ranges in thickness from 50 to 150 feet with an average of about 125 feet. The sand varies greatly in porosity and has

*Matson, G. C., and Hopkins, O. B., The DeSoto-Red River oil and gas field, La., Bull., U. S. Geol. Survey No. 661, p. 101-140, 1917.

many irregular indurated layers. So far the Nacatoch has yielded much gas but little oil. The gas wells have capacities of as much as 15,000,000 cubic feet per day. Small quantities of oil have been found in the Annona chalk.

The principal oil-bearing sand lies about 1,660 feet below the Nacatoch sand. The sand zone is from 50 to 100 feet thick but the individual beds are lenticular and are intercalated with shale and hard layers. The exact position of the sand in the section is not known. The wells in this sand have initial productions of up to 8,000 barrels per day and 1,000-barrel wells are not uncommon. The oil is generally of high grade, ranging from 38 to 42.5 degrees Baume. The oil from Red River Parish averages somewhat better than that from De Soto Parish.

The deep gas sand lies 150 to 200 feet below the oil sand. The sand occurs as well-defined beds which are persistent for some distance. This sand is more uniformly productive over the area than the shallower sands which are very spotted. Wells in the deep gas sand reach 35,000,000 cubic feet per day in initial capacity.

The structure as contoured on the Nacatoch sand is somewhat complex. The main structure is the Sabine uplift which has its axis extending from west of north to south of east. On this are superimposed several small folds and terraces, as follows:

The Naborton dome has its highest part in secs. 5 and 7, T. 12 N., R. 11 W. There is a shallow syncline on the north flank and the western margin is complicated by small pitching anticlines and synclines. The south edge of the dome is formed by a fault known os the Gusher Bend Fault.

The Smithport anticline extends in a northeast southwest direction across secs. 22, 28 and 32, T. 13 N., R. 12 W. The fold is lower than the Naborton dome and has more gentle dips.

The Bice anticline lies south of the Naborton dome in secs. 4, 5, and 6, T. 12 N., R. 11 W. It is lower and has more gentle dips than the layer folds to the north.

The Crichton terrace is in secs. 19, 20 and 30, T. 13 N., R. 10 W. It is a broad flattening probably separated by a shallow syncline from the folds to the southwest. The Terrace is wrinkled by small anticlines and synclines.

The Gusher Bend anticline is associated with the Crichton terrace, and is located in secs. 24, 25 and 36, T. 13 N., R. 11 W.

The Gusher Bend fault which bounds the Crichton terrace, Gusher Bend anticline and Naborton dome on the south has a maximum displacement of over 200 feet with the downthrow on the south. There are probably other smaller faults in the area with their area parallel to that of the Gusher Bend fault.

The production is closely related to the structure but does not coincide with them. The lenticularity of the sands has probably

had an important effect in locating the accumulations. As in the case in the Caddo field, the structures in the different sands are not the same and, in general, the deeper sands are more steeply folded.

The production is very spotted and the proportion of dry holes is high.

During 1919 there has been great activity in the Bull Bayou area in the eastern end of the district, in Red River parish.

Shreveport gas field—A gas field near Shreveport has furnished considerable gas from the Vacatoch sand. The structure is probably a cross fold on the Sabine uplift comparable to those in the Caddo and De Soto-Red River folds. The gas is closely associated with salt water.

Pelican district—Several wells have produced small quantities of oil in the vicinity of Pelican. The wells are scattered over an area about 7 miles long in Tps. 10 and 11 N., R. 12 W., in southern De Soto and northern Sabine Parish. The productive horizon is thought to be the oil sand of the De Soto-Red River field.

Development at Homer—Early in 1919 an oil well was brought in about 7 miles west of Homer in Clarborne parish. The offset well also was a good producer. Two wells about a mile to the north were drilled and abandoned some time ago, but both are reported to have had considerable oil. There are some surface indications of favorable structure in this vicinity and the prospects for developing a pool of some magnitude seem good.

Monroe gas field—Several large gas wells have been developed near Monroe, but no oil has been reported as yet.

At the end of 1917 the field was about 10 miles long and wells of as high as 40,000,000 cubic feet per day capacity had been brought in.

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VIII.

NATURAL GAS IN THE MID-CONTINENT FIELDS.

In the description of the different producing fields, the natural gas producing fields have been described as well as those producing oil and where a pool produces both gas and oil some reference to the gas production has been made.

However, the natural gas industry is of sufficient importance to merit separate consideration.

The annual review for 1916, by John D. Northrop in the Mineral Resources of the United States, published by the United States Geological Survey gives a complete review of the situation in the natural gas industry to the end of 1916 and is the latest published information.

The following pages are taken entirely from that report.

KANSAS.

GENERAL STATEMENT.

The natural gas industry in Kansas dates back to 1873, when gas from the Acers Mineral Well at Iola, Allen county, was used as an illuminant in a neighboring sanitarium erected for the primary purpose of exploiting the medicinal properties of the mineral water obtained from the same well. In 1882 gas was found in abundance in wells drilled 7 miles north of Paola, Miami county, and in 1884 mains were laid from this district to Paola and the distribution of gas to consumers in that town was begun. About 1887 natural gas from nearby wells was introduced into the town of Fort Scott, Bourbon county, and in 1892 the distribution of gas from wells of large capacity west and northwest of Coffeyville, Montgomery county, was begun in the latter town. In 1893 Cherryvale, in the northeastern part of the same county, was first supplied with natural gas from wells east of town, and Independence, near the center of the county, was supplied from wells 4 miles to the east. The adoption of natural gas as a fuel in the zinc smelters at Cherryvale in 1898 established the natural gas industry in Kansas on a permanent basis, and its subsequent development was rapid. In 1905 natural gas mains were laid from the fields in Montgomery county to the Joplin lead and zinc district in southwestern Missouri and in 1906 gas from the Allen and Neosho county fields was piped into Kansas City.

From only a few hundred dollars in 1882 the value of the gas produced annually in Kansas increased slowly to $50,000 in 1893, then rapidly to $112,000 in 1895, to $1,124,000 in 1903 and to a maximum of $8,294,000 in 1909, subsequent to which it declined steadily to $3,288,000 in 1913, since which year it has gradually increased with the development of prolific gas fields in Butler county, though it is still far below the maximum.

Natural gas was produced profitably in Kansas in 1916 in 23 counties, all in the eastern third of the state. Petroleum and natural gas in this state occur in sandstone or limestone layers in the Pennsylvanian series ("Coal Measures"), the most productive zone being that of the Cherokee shale, at the base of the series. Lenticular sandstone layers interbedded with the Cherokee shale constitute the principal reservoirs of oil and gas in the state.

PRODUCTION.

The volume of natural gas produced in Kansas in 1916 was greater than that produced in this state in any other recent year since 1911. It amounted to 31,710,438,000 cubic feet and exceeded the output in 1915 by 4,664,530,000 cubic feet or 17 per cent. The value of this gas at the point of consumption was $4,855,389, a gain of $818,378, or 20 per cent, over the value of the output in 1915, this gain being accounted for in part by the increased volume of gas and in part by an increase from 14.93 cents to 15.31 cents in the average price per thousand cubic feet at which the gas was sold in 1916.

Credit for the augmented production in 1916 belongs almost wholly to Butler county and was due principally to the extensive activity in the quest for petroleum in the Augusta and Eldorado districts in that county. In all 75 new gas wells were completed, 7 exhausted wells were abandoned, and 234 gas wells were in service in Butler county in 1916, exclusive of the wells that produced both gas and petroleum.

In Chautauqua and Montgomery counties the usual activity in the quest for natural gas prevailed, but no new territory of consequence was added to the areas already proved productive.

In the state as a whole activity in drilling for natural gas was less than in 1915 and was attended with poorer success, as far as the number of wells is concerned. In 1916 a total of 654 wells were drilled for gas, of which 461, or 70 per cent, were successful and 193, or 30 per cent, were unsuccessful. In 1915 there were 748 wells completed, of which 554, or 74 per cent, were successful. The number of unsuccessful tests reported in 1916 was only 1 less than the number reported in 1915. At the end of 1916 there were 2,513 gas wells, exclusive of the wells that produce both oil and gas, in

service in Kansas, a net gain of 70 wells over the number in service at the end of 1915.

CONSUMPTION.

Including a relatively small volume of natural gas piped to Missouri and consumed in the smelter district about Joplin, the volume of natural gas consumed in Kansas in 1916 was 60,564,112,-000 cubic feet, a gain of 11,692,817,000 cubic feet, or 24 per cent, over the volume consumed in 1915.

The market value of this gas was $9,731,518, a gain of $1,-557,229, or 19 per cent, over the value of the gas consumed in Kansas in 1915. The failure of the total market value to increase in the same ratio as the volume of gas consumed is accounted for by a decrease from 16.73 cents to 16.07 cents in the average price per thousand cubic feet in 1916.

It is estimated that 20,876,693,000 cubic feet of gas, or 34 per cent of the total volume consumed in Kansas in 1916, valued at $5,314,011, or 55 per cent of the total market value, was distributed to 202,222 domestic consumers in Kansas and southeastern Missouri at an average price of 25.45 cents a thousand cubic feet, and that the remaining 66 per cent of the volume, representing 45 per cent of the total market value of the gas consumed, was distributed to 1,354 industrial consumers at an average price of 11.13 cents a thousand.

With regard to the consumption of natural gas for domestic purposes in Kansas in 1915 and 1916, a comparison of the statistics for the two years shows in 1916 gain of only 1 per cent in volume and of 0.5 per cent in the number of consumers supplied, but loss of 0.3 per cent in the total market value of the gas involved on account of a decrease of 0.38 per cent, or 1.5 per cent in the average price per thousand paid for natural gas service by this class of consumers.

The average volume of natural gas consumed monthly by each domestic consumer in Kansas in 1916 was 8,600 cubic feet at an average monthly cost of $2.19.

With regard to the consumption of gas for industrial purposes a comparison of the statistics for the same two years shows in 1916 loss of 7 per cent in the number of consumers, but gain of 40 per cent in the volume of gas consumed, of 55 per cent in the total market value of that gas, and of nearly 11 per cent in the average price per thousand paid for it.

Much of the increase recorded is accounted for in the greatly augmented requirements of natural gas for fuel in lead and zinc smelters. It is estimated that in 1916 a total of 15,542,197,000 cubic feet of gas, valued at $1,750,726, was distributed at an average price of 11.26 cents a thousand, to the smelters. Comparison of these data with corresponding items for 1915 shows in 1916

gain of 82 per cent in the volume of gas consumed in Kansas in the smelting of metals, of 106 per cent in the total market value of that gas, and of 1.36 cents, or 14 per cent, in the average unit price paid for it.

About 2,690,917,000 cubic feet of gas, valued at $242,457, an average price of 9.01 cents a thousand, was distributed in 1916 to cement plants in Kansas, and about 3,962,940,000 cubic feet, valued at $362,070, an average price of 9.14 cents a thousand was distributed to manufacturers of brick, glass and clay products.

RECORD OF NATURAL GAS INDUSTRY IN KANSAS, 1898-1916.

Year	Gas Produced		Gas Consumed			Wells		
			No. Consumers			Drilled		
	No. Pdcrs.	Value	Domestic	Industrial	Value	Gas	Dry	Prod. Dec. 31
1898	29	$174,640	*6,186	44	$174,640	34	18	121
1899	31	332,592	*10,071	71	332,592	44	22	160
1900	32	356,900	*9,703	65	356,900	54	15	209
1901	48	659,173	*10,227	72	659,173	71	35	276
1902	80	824,431	13,488	91	1,123,849	144	63	404
1903	120	1,123,849	15,918	143	1,517,643	295	66	666
1904	190	1,517,643	27,204	298	2,265,945	378	135	1.029
1905	171	2,261,836	46,852	601	†4,023,566	340	157	1,142
1906	130	4,010,986	79,270	990	†6,208,862	331	99	1.495
1907	196	6,198,583	149,327	1 605	†7,691,587	361	163	1.760
1908	212	7,691,587	168,855	1,162	†8,356,076	403	208	1,917
1909	199	8,293,846	182,657	1,160	$24,431	452	214	2,138
1910	204	7,755,367	186,333	1,412	‡9,493,701	392	195	2,149
1911	232	4,854,534	199,523	907	‡9,335,027	301	152	2,033
1912	253	4,264,706	195,446	1,104	‡8,521,858	435	200	2,106
1913	305	3,288,394	195,131	950	‡6,983,802	506	253	2,297
1914	353	3,340,025	187,714	1,079	†7,163,746	445	219	2,261
1915	371	4,037,011	201,133	1,446	†9,731,518	461	193	2,513
1916	414	4,855,389	202,222	1,354	†8,174,289	554	194	2.443

*Number of fires supplied.

†Includes gas taken from Kansas and consumed in Missouri.

‡Includes gas taken from Kansas to Missouri; also gas piped from Oklahoma to Kansas and Missouri.

DEPTH AND ROCK PRESSURE OF WELLS IN KANSAS, 1912-1916.

County	Depth (Ft.)	Pressure (Pounds)				
Allen	500—1,500	10—300	5—260	6— 240	5—300	4—270
Anderson	230—1,070	30—240	65—250	65— 225	60—225	60—165
Bourbon	150— 800	40	75	75	80	------
Chase	64—1,100	7— 80	3— 95	10—*160	6—160	8—130
Cowley	575—1,500					
Chautauqua	300—1,900	50—300	35—410	40— 210	25—425	20—600
Crawford	97— 680	15— 50	40— 50	30— 90	40—176	25— 80

*New wells.

DEPTH AND ROCK PRESSURE OF WELLS IN KANSAS, 1912-1916—Continued.

County	Depth (Ft.)	Pressure (Pounds)				
		1912	1913	1914	1915	1916
Douglas	350— 550	10— 280	20— 60	10—*130	55— 80	20—610
Johnson	130— 950	125— 270	240— 270	160— 250	200—250	195—275
Ellsworth	950—1,250	100	90— 100	75	100—550	40
Elk	500—1,887	60—*525	550—*560	*400—*600	30—300	300—500
Butler	1,330—2,650			90—*250	125	200
Woodson	650—1,430	--------	--------	--------	--------	--------
Greenwood	350— 400	23— 185	20— 240	50— 200	50—300	42—195
Labette	320—1,000	6— 70	20— 100	20— 100	15—110	10—100
Linn	85— 750	3— 260	1— 500	50— 240	40—112	112
Franklin	300— 720	2—*515	5— 700	40— 120	50—100	45—100
Miami	200—1,150		15— 325	15— 400	8—150	15—175
Montgomery	160—1,600	--------		--------	300	250
Morris	600	28— 250	--------	25—*360	6—260	0—260
Neosho	281—1,200	15— 380	15— 285	12—*350	7—600	30—475
Wilson	250—1,725	40— 125	30— 125	85	0—140	15— 75
Wyandotte	271— 800					

*New wells.

OKLAHOMA.

GENERAL STATEMENT

The natural gas resources of Oklahoma are closely associated with petroleum and the development of the natural gas industry in this state has closely paralleled the development of its vast resources of petroleum. The earliest recorded use of natural gas on a commercial scale in Oklahoma was at Red Fork, Tulsa county, where it was used as fuel for drilling purposes and as a source of heat and light in a few houses in 1902. In 1903 natural gas was used for drilling purposes near Lawton, Comanche county, near Pawhuska, Osage county, and near Newkirk, Kay county. In 1904 natural gas was distributed to domestic consumers in Tulsa, Bartlesville, Ochelata, Pawhuska, and Red Fork, and to brickworks near Red Fork. The subsequent growth of the natural gas industry in Oklahoma has been rapid and has by no means spent its force. Since 1911 Oklahoma has ranked third among the gas producing states, on the basis of the volume of gas produced, and its advance to second place in 1917 seems inevitable.

Natural gas was produced profitably in Oklahoma in 1916 in 31 counties lying in the eastern half of the state.

Petroleum and natural gas in Oklahoma are found in sandstone and, less commonly, in limestone layers of variable thickness occurring at numerous horizons in the succession of strata between the base of the Mississippian series (lower Carboniferous) below and the lower portion of the Permian series above. By far the greater part of the production, both of petroleum and of natural

gas, is derived from "sands" in the intervening Pennsylvanian series (upper Carboniferous.)

PRODUCTION.

The volume of natural gas produced profitably in Oklahoma in 1916 exceeded the volume so produced in this state in any preceding year. This volume, which is estimated at 123,517,385,000 cubic feet, was greater by 36,000,632,000 cubic feet, or 41 per cent, than the output in 1915, which was itself a record yield.

The market value of this gas was $11,983,774, a gain of $2,787,970, or 30 per cent, over the value of the gas produced in 1915. The failure of the statistics of value to record an increase commensurate with the volume is accounted for by the facts that they are based on the prices received for gas at the point of consumption and that relatively more Oklahoma gas was distributed at industrial rates than at domestic rates in 1916, as compared with 1915.

The influence of the increased distribution of gas to industrial consumers is shown in the statistics of the average price per thousand received for Oklahoma gas in 1916. This was 9.70 cents, compared with 10.51 cents in 1915, a loss of 0.81 cents, or nearly 8 per cent, in 1916.

The greater part of the gas produced in Oklahoma in 1916 came from the Cushing district and its southward extension, the Shamrock district, in Creek county. In the Cushing district the open-flow capacity of the gas wells completed in 1916 averaged appreciably lower than that of the wells completed in 1915. Development work in the Shamrock district resulted in the completion of many gas wells of large capacity, the largest of which was probably the initial well of the McMann Oil company, on the Williams farm in sec. 4, T. 16 N., R. E. This well was completed early in February and was credited with an initial open-flow capacity of 70,000,000 cubic feet of gas a day from the Bartlesville sand. The completion of wells credited with initial open-flow capacities of 30,000,000 to 50,000,000 cubic feet of gas a day was by no means an uncommon feature of the development work in this district in 1916. Some of the gas produced in this district was unavoidably lost, but much of it was either piped away for immediate consumption or sealed off in the productive sands for future use.

In western Pawnee county new territory of considerable promise was opened in January, 1916. The initial test was drilled by Watchorn and others in sec. 32, T. 23 N., R. 3 E., and was completed as a gas well credited with a capacity of 35,000,000 cubic feet from two sands reached at reported depths of 1,840 and 2,150 feet.

Near Ingalls in the east central part of Payne county, a prolific area of gas production was proved in 1916 in secs. 27 and 34,

T. 19 N., R. 4 E., one well in sec. 27 of this township completed in August by the Fortuna Oil company being credited with an initial open-flow capacity of 60,000,000 cubic feet of gas a day. In the southern part of Washington county a number of gas wells ranging in initial open-flow capacity between 5,000,000 and 10,000,000 cubic feet a day were completed by the Quapaw Gas company, in 1916 near Ochelata. The interesting feature of this district lies in the fact that the gas is obtained from what is believed to be the Pitkin limestone, near the top of the Mississippian series and in this locality about 300 feet below the Bartlesville sand, the principal source of oil and gas in northeastern Oklahoma.

In the Blackwell district, Kay county, the results of drilling in 1916 added further proof of the enormous potentialities for gas production possessed by this district. A few gas wells of large capacity were completed during the year, but in most of the wells the gas was "mudded off" in the productive sand for future use.

In Noble county natural gas territory of much promise was opened in July near Billings by the completion as a gas well having an estimated initial capacity of 6,000,000 cubic feet of a wildcat test drilled by the Mid-Co. Petroleum company on the Hoover farm in sec. 22, T. 23 N., R. 2 W.

In the southeastern part of Wagoner county development work in the Stone Bluff pool, discovered late in 1915, resulted in the completion of a number of prolific gas wells.

The discovery at a depth of 2,972 feet of a flow of gas estimated at 5,000,000 cubic feet a day in a test well drilled in sec. 16, T. 8 N., R. 11 E., aroused considerable speculation as to the presence of an important gas field near Lamar, Hughes county.

Aside from the occasional completion of a prolific gas well in the southeastern part of the Healdton district, Carter county, interest in natural gas developments in this locality in 1916 was centered in the Fox pool, 6 miles north of this district, where it will be recalled a gas well credited with an initial capacity of 20,000,000 cubic feet was completed by the Gypsy Oil company late in December, 1915. During 1916 gas from this well was utilized as fuel for the drilling of additional wells in this locality and was piped to Ardmore to increase the failing supply piped to that city from the old Wheeler field. In October, 1916, one additional gas well was completed in this new field. It was drilled by Phillips & Franklin in sec. 29, T. 2 S., R. 3 W., and was credited with an open-flow capacity of 45,000,000 cubic feet of gas. Late in December well No. 2 of the Gypsy Oil company, in Sec. 28, was drilled into a prolific gas sand encountered at a reported depth of 2,080 feet, and at the end of 1916 efforts were being made to seal off the productive sand in order that the well might be deepened. Its open-flow capacity was estimated at 50,000,000 cubic feet of gas a day.

Exclusive of the wells that yielded both oil and gas there were 386 gas wells completed in Oklahoma in 1916. At the end of the year 1,409 gas wells were in service in this state.

Aside from supplying the gas required by consumers residing in Oklahoma, the gas fields of this state supplied a large volume of natural gas to consumers in Missouri, Kansas and Arkansas.

CONSUMPTION.

Including the gas piped from Oklahoma to the lead and zinc district of southwestern Missouri, the volume of natural gas consumed in Oklahoma in 1916 was about 93,704,221,000 cubic feet. This volume was greater by 28,012,855,000 cubic feet, or 30 per cent, than the volume consumed in 1915. Its market value was $7,062,142, a gain of $2,003,616, or 28 per cent, over the value of the gas consumed in 1915.

The average price per thousand paid by all classes of consumers to which this gas was distributed, was 7.54 cents in 1916, compared with 7.70 cents in 1915 and 7.61 cents in 1914.

Of the total volume of gas consumed in 1916 it is estimated that 10,723,336,000 cubic feet, market value $1,915,758, was distributed to 79,724 domestic consumers, at an average price of 17.87 cents a thousand, and that the remaining volume of 82,980,885,000 cubic feet, market value $5,146,384, was distributed to 2,327 industrial consumers, at an average price of 6.20 cents a thousand.

Comparison of the statistics of natural gas consumption for domestic purposes in 1915 and 1916 shows in 1916 increase of 11,850, or 17 per cent, in the number of consumers favored with natural gas service, but of only 7 per cent in the volume of gas used, and of 6 per cent in its total market value, despite a reduction of 0.10 cent, or 1 per cent, in the average price per thousand paid for the gas. Calculation based on the total number of domestic consumers favored with natural gas service at the end of 1916 indicates that the average monthly consumption of natural gas by each consumer in 1916 was 11,200 cubic feet and that the average monthly cost of this service was only $2. The average actual consumption was undoubtedly slightly greater than is indicated by these figures as a consequence of the fact that 17 per cent of the domestic consumers were supplied with gas during only a part of the entire year.

Comparison of the statistics of natural gas consumed for industrial purposes in the same two years shows in 1916 gain of 110, or 25 per cent, in the number of consumers supplied, of 49 per cent in the volume of gas consumed, of 58 per cent in the market value of that gas, and of 0.35 cent, or 6 per cent, in the average price per thousand paid for it.

A further analysis of the statistics of natural gas consumed for industrial purposes in 1916 indicates that 46,246,844,000 cubic feet market value $2,701,158, was distributed to 366 industrial plants for direct consumption in manufacturing processes, such as the smelting of metals, the making of glass, the burning of brick, and the manufacture of carbon black, at an average price of 5.84 cents a thousand, and that the remaining 36,734,041,000 cubic feet, market value $2,445,226, was distributed to 1,961 industrial plants for use as fuel in the generation of power, as in gas engines and under steam boilers, at an average price of 6.66 cents a thousand.

Of the volume distributed in 1916 for direct use in manufacturing it is estimated that 26,209,069,000 cubic feet. market value $1,385,059, an average price of 5.3 cents a thousand, was consumed in the smelting of metals in Oklahoma. Compared with the consumption for this purpose in 1915 these data show in 1916 gain of 62 per cent in volume, of 73 per cent in market value, and of 0.4 cent, or 8 per cent, in average price per thousand.

Smelters in Oklahoma supplied with natural gas in 1916 are located as follows: Bartlesville, 3 plants, owned by the National Zinc company, and the Bartlesville Zinc company, Collinsville, 2 plants, owned by the Bartlesville Zinc company and the Tulsa Fuel & Manufacturing company; Henryetta, 3 plants, owned by the Western Spelter company, the Henryetta Spelter company, and the Eagle-Picher Lead company; Kusa, 2 plants, owned by the Kusa Spelter company, and the Oklahoma Spelter company; Checotah, 1 plant, owned by the United States Smelting company; Quinton, 1 plant, owned by the Quinton Spelter Company; Sand Springs, 1 plant, owned by the United States Zinc company; and Blackwell, 1 plant, owned by the Bartlesville Zinc company.

RECORD OF NATURAL GAS INDUSTRY IN OKLAHOMA, 1906-1916.

	Gas Produced		Gas Consumed			Wells		
			No. Consumers					
	No.		Domes-	Indus-		Drilled		Prod.
Year	Pdcrs.	Value	tic	trial	Value	Gas	Dry	Dec. 31
1906	50	$259,862	8,391	202	$247,282	81	33	239
1907	107	417,221	11,038	277	406,942	99	41	344
1908	115	860,159	17,567	356	860,159	73	40	374
1909	131	1,806,193	32,907	1,527	1,743,963	97	35	454
1910	168	3,490,704	38,617	1,557	1,911,044	93	58	509
1911	204	6,731,770	44,854	1,507	2,092,603	303	143	732
1912	242	7,406,528	47,017	1,651	3,149,376	329	197	936
1913	347	7,436,389	49,308	1,793	3,740,981	423	298	1,052
1914	437	8,050,039	62,390	1,951	*4,226,318	398	182	1,205
1915	434	9,195,304	67,874	1,551	*5,058,526	209	118	1,229
1916	544	11,983,774	79,724	2,327	*7,062,142	386	231	1,409

*Includes some gas piped from Oklahoma to Missouri.

DEPTH AND ROCK PRESSURE OF WELLS IN OKLAHOMA, 1912-1916.

County	Depth (Ft.)	Pressure (Pounds)				
		1912	1913	1914	1915	1916
Cherokee	600— 650	--------	--------	--------	--------	--------
Hughes	1,000—2,000	200	10—350	--------	500	400
Carter	590—2,000			30— 325	50—370	300—900
Comanche	340—1,000	--------	--------	286— 400	78	200—250
Craig	500— 520					
Latimer	1,575—1,600	--------	--------	151— 400	--------	--------
Sequoyah	1,200					
Creek	400—2,900	40—850	20— 900	40— 800	40—400	75—690
Garfield	1,150—1,170	--------	———			
Kay	400—3,400	165—365	40— 650	--------	--------	--------
Kiowa	350— 825	--------	--------	35— 450	50—*1,500	40—*1,200
Le Flore	1,300—3,000	350—355	300— 375	30	--------	--------
McIntosh	962—2,740			385	140—350	260—350
Marshall	420— 600	150—600	150— 400	*900	110—*1,200	500—610
Mayes	102— 640	--------	--------	150	135—150	150—225
Muskogee	700—2,200	15—350	10— 350	--------	40— 80	5— 45
Nowata	450—1,700	25—150	25—300	20— 275	20	120—805
Okfuskee	1,450—2,460	--------	--------	39— 150	85—310	--------
Okmulgee	600—2,600	300	80—*800	*790	*790	700—790
Osage	750—2,500	200—780	100— 700	80—*840	800—*1,000	60—710
Pawnee	1,000—3,150	40—800	--------	150—*800	150—680	50—740
Coal	400—3,300			--------	*860	800
Pittsburg		--------	--------			100—550
Pontotoc	1,000—3,000	--------	--------	110— 425	--------	
Greer	390— 565	--------	--------	--------	--------	--------
Payne	2,940—3,150	--------	--------	*800	*900	400
Rogers	380—1.800	40—525	25— 500	145— 400	50—350	30—400
Stephens	600—1,200	300—325	250— 330	240— 345	283	156
Tulsa	580—2,200	50—625	100— 650	70— 525	40—600	30—500
Wagoner	550—1,700	--------	--------	165— 405	230—325	206—520
Washington	315—2,260	10—250	19— 350	25—*635	30—300	50—400

LOUISIANA.

PRODUCTION.

The volume of natural gas produced in Louisiana in 1916 was greater than that produced in this state in any preceding year in the history of the local gas industry. It amounted to approximately 32,080,975,000 cubic feet, and at the average selling price of 8.29 cents a thousand cubic feet, added $2,660,445 to the mineral wealth of the state in that year.

Compared with statistics for 1915 these data show gain in 1916 of 6,540,583,000 cubic feet, or 26 per cent, in the volume of gas produced, and of $496,511, or 23 per cent, in its total market value, but a decline of 0.18 cent, or 2 per cent, in the average unit price at which this gas was sold.

As the available supply of natural gas in Louisiana is considerably in excess of the facilities for marketing it, the increase in production can be accounted for in part by the extension of existing transmission lines. As the production of natural gas in this

state is largely incidental to the development of its oil fields, some part of the increase in gas production in 1916 must be ascribed to the fact that activity in the quest of petroleum in Louisiana was 18 per cent greater in that year than it was in 1915. Other factors contributing to this increase include augmented demands for natural gas for drilling purposes in the oil fields for consumption as fuel by large industrial consumers, and for utilization in five new plants for the extraction of gasoline from natural gas installed in this state in 1916.

A fair proportion of the increased output of natural gas in Louisiana in 1916 came from wells in the immediate vicinity of Shreveport in the southern part of Caddo parish. The remarkable success attained in the quest of natural gas in this locality in 1915 resulted in the drilling of additional wells in 1916 and in the completion of a number of gas wells of large capacity in the Harts Island district, just south of Shreveport, in the Cross Lake district, a few miles west of this city, and in the area northwest of Shreveport, between this city and Blanchard.

Persistent efforts, over a period of several years, to find petroleum in commercial quantities in Bossier Parish were rewarded in 1916 by the discovery of a prolific gas field in the vicinity of Elmgrove, about 20 miles southeast of Shreveport. The discovery well drilled by the Atlas Oil company, was completed in January on the Elston lease in sec. 20, T. 16 N., R. 11 W., and was credited with an initial flow of 3,000,000 cubic feet of gas a day from a sand reached at a depth of about 900 feet. The completion of well No. 2 on this lease in February as a 30,000,000-foot gasser furnished the real incentive for additional drilling in this locality. Several gas wells of large capacity were completed in this new field during 1916, but to the end of the year the only market for the gas was the very limited one provided by the requirements for drilling purposes of companies operating in the same field.

A gas field of considerable potential importance was also discovered in 1916 in Morehouse Parish, in the northeastern part of Louisiana. The discovery well drilled by the Progressive Oil & Gas company, was completed in September on the Spyker tract in sec. 9, T. 20 N., R. 5 E., and was credited with an initial open-flow capacity estimated at 5,000,000 cubic feet a day and a rock pressure of 800 pounds to the square inch, from a sand reached at a depth of about 2,200 feet. The completion in November by the same company of its second well, No. 1 Fisher, in Sec. 33 of the township to the north, as a 10,000,000-foot gasser at a depth of about 2,250 feet resulted in the starting of a number of other wells in southern Morehouse and northern Ouachita parishes, which, however, remained uncompleted to the end of 1916. Plans were made to pipe

the gas from this field to Bastrop, Monroe, and West Monroe in 1917.

The greater part of the natural gas produced in Louisiana in 1916 came as usual from the oil districts in Caddo, De Soto, and Red River parishes; a small percentage, however, consumed near the source of production, was obtained from scattered wells in Natchitoches, Rapides, Richland, La Fourche, Ouachita, Claibourne, Calcasieu, Terrebonne, and Vermilion parishes.

During 1916 the number of producers of natural gas in Louisiana increased from 57 to 78, and at the end of that year there were 263 gas wells in service in the state, compared with 253 at the end of 1915.

CONSUMPTION.

Including the gas piped from Louisiana to adjacent parts of Arkansas and Texas, the volume of natural gas consumed in Louisiana in 1916 was equivalent to the volume produced, as no gas from other states is consumed in this state.

Of the total volume consumed in 1916 about 3,890,552,000 cubic feet, or 12 per cent, valued at $1,149,336, or 43 per cent of the total market value of the gas consumed, was distributed to 32,257 domestic consumers at an average price of 29.54 cents a thousand, the remaining 88 per cent of the volume, representing 57 per cent of the total market value, being distributed to 679 industrial consumers at an average price of 5.36 cents a thousand. Compared with statistics of the consumption of Louisiana gas in 1915, these data show in 1916 gain of 7 per cent in the number of consumers, of 2 per cent in the volume, of 11 per cent in the market value, and of 2.67 cents, or 10 per cent, in the average price per thousand feet of gas supplied to domestic consumers, and gain of 14 per cent in the number of consumers, of 30 per cent in the volume, of 33 per cent in the market value, and of 0.14 cent, or 2 per cent, in the average unit price of gas distributed to industrial consumers.

On the assumption that an average of 31,200 domestic consumers were supplied with Louisiana gas each month in 1916, the average monthly consumption of each consumer in that year was 10,400 cubic feet, and the average monthly cost of natural gas service to each domestic consumer was $1.96.

No material changes were made in 1916 in the natural gas distributing systems in Louisiana, as outlined in the report of this series for 1915.

RECORD OF NATURAL GAS INDUSTRY IN LOUISIANA, 1909-1916.

Year	No. Pdcrs.	No. Consumers Domestic	Industrial	Ttl. Val. of Gas Produced	Wells Drilled Gas	Dry	Prod. Dec. 31
1909	11	4,034	164	*$326,245	26	10	85
1910	21	8,547	320	*509,408	23	4	97
1911	27	†17,964	442	*858,145	36	18	119
1912	41	†24,087	474	*1,747,379	50	20	150
1913	57	†26,424	550	*2,119,948	53	24	111
1914	54	†29,751	618	*2,227,999	52	26	239
1915	57	†30,144	597	2,163,934	35	10	253
1916	73	†32,257	679	2,660,445	48	47	263

*Includes the production of Alabama.
†Includes consumers supplied with gas piped from Louisiana to Arkansas and Texas.

DEPTH AND ROCK PRESSURE OF WELLS IN LOUISIANA, 1912-1916.

Parish	Depth (Ft.)	Pressure (Pounds) 1912	1913	1914	1915	1916
Bossier	800—2,463	--------	--------	--------	--------	300—1,000
Caddo	750—3,224	80—910	60—850	20—325	40—300	24—1,000
De Soto	746— 905	400—450	350—450	338—716	*466	100— 260
Lafourche	80— 100	25	20	5— 10	15	--------
Morehouse	2,232—2,266	--------	--------	--------	--------	1,000—1,140
Natchitoches	1,010	--------	--------	--------	--------	20
Ouachita	1,200—3,240	--------	--------	Small	--------	1,050
Red River	904—2,668	--------	--------	--------	*400	100— 950
Terrebonne	93— 126	--------	--------	50	34	18— 35

*New well.

TEXAS.

PRODUCTION.

The volume of natural gas produced and utilized in Texas in 1916 was greater than in any preceding year in the history of the natural gas industry in the state. It amounted to 15,809,579,000 cubic feet, a gain of 2,485,832,000 cubic feet, or 19 per cent, over the volume produced in 1915, and was 18 per cent larger than the record yield of 13,433,639,000 cubic feet in 1914.

The market value of the output in 1916 was $3,143,871, a gain of $549,998, or 21 per cent, over the value of the output in 1915, and of $674,101, or 27 per cent, over the value of the output in 1914.

The average price at which Texas gas was sold in 1916 was 19.89 cents a thousand cubic feet, a gain of 0.42 cents, or about 2 per cent, over the average in 1915, and of 1.51 cents, or about 8 per cent, over the average in 1914.

The increase in the volume of natural gas produced in Texas in 1916 is accounted for principally by the extension of facilities for natural gas consumptionu rather than by the development of strictly new sources of production. The principal contributor to the increased yield was the Strawn district in Palo Pinto county, which in 1916 furnished a large volume of natural gas to industrial plants and to a few domestic consumers at Thurber. Production of gas in

the Mexia district, Limestone county, was materially increased in 1916 as a result of the extension of natural gas service to a large number of domestic consumers in the city of Waco in that year. A part of the increase is ascribed also to the increased conservation of oil-field gas in the oil districts of north-central Texas as a consequence of the operation there of four plants for the manufacture of casing-head gasoline in 1916, compared with one plant in 1915.

The principal area of the commercial production of gas in Texas is the Petrolia oil and gas district, in Clay county, which supplies the gas consumed in Dallas and Fort Worth, as well as in a number of other cities and towns in north-central Texas. The drain on this field necessary to supply the needs of these communities had so diminished the pressure and volume of gas in 1916 that on September 30 the principal distributor of gas from the Petrolia field was compelled to forego the distribution of gas to industrial consumers in order that the supply remaining might be conserved for the benefit of domestic consumers. This action, though regrettable, is amply justified by the principles of true conservation, which require that natural resources shall be exploited on the basis of the greatest good to the greatest number. At the end of 1916 there were 56 gas wells in the Petrolia district, exclusive of a few wells that produced both gas and oil. Thirteen new gas wells were completed and 13 were abandoned in this field in 1916. The average closed pressure of the wells in the Petrolia field was about 175 pounds to the square inch at the end of 1916, a decline of 65 pounds during the year, against 90 pounds in 1915 and 180 pounds in 1914.

Second in importance as a source of natural gas in Texas is the Mexia-Groesbeck field, in Limestone county, which supplies the gas consumed in Waco and Corsicana, as well as in a number of towns in the immediate vicinity of the field. The volume of gas marketed from this field in 1916 was greater than in any other year since the field was discovered in 1912. Twelve gas wells were completed and 6 exhausted wells were abandoned in this field in 1916, and at the end of the year 53 gas wells were in service. The average closed pressure of these wells was 180 pounds to the square inch at the end of 1916, compared with 200 pounds at the end of 1915, 240 pounds at the end of 1914, 273 pounds at the end of 1913, and 275 pounds at the end of 1912.

In the Moran oil and gas field in Shackelford county, which supplies the gas consumed in the towns of Moran, Baird, Clyde, Putnam, and Abilene, there were no important developments in 1916. North of the Moran district in Throckmorton county a gas well of small capacity was completed in March on the Matthews ranch, a short distance from a similar well drilled three years earlier.

The piping of natural gas to consumers in and near Thurber, Erath county, in 1916, directed attention to the source of that gas

in the Strawn district, Palo Pinto county. This field, which lies about 2 miles southwest of Strawn, was discovered in 1914 by the Texas & Pacific Coal company in the course of test drilling to determine the position and thickness of a coal bed in that locality. With the discovery of petroleum to the north of the gas pool in 1915 little effort was made to utilize the gas for the purposes other than drilling until 1916. At the end of 1916 there were about 50 wells with a combined capacity of perhaps 65,000,000 cubic feet of gas a day in this field. These wells range in depth from 900 to 1,800 feet and in closed pressure up to 650 pounds to the square inch. Many of them are capped, awaiting the provision of facilities for the marketing of their product.

A new gas field of considerable promise was opened in 1916 in the eastern part of Palo Pinto county. The initial well in this field was drilled near the end of 1915 on the Hess ranch, 5 miles south of Mineral Wells, and, after encountering gas in fair volume in a sand reached at a depth of 720 feet, was drilled deeper in quest of oil and ultimately lost by flooding in January, 1916. A second well a few hundred feet to the northeast, completed in February, 1916, was credited with an initial capacity of 3,000,000 cubic feet of gas from a sand found at a reported depth of 1,060 feet. The completion in March as a gas well of fair capacity of a test on the Edmonson ranch. 7 miles south of Mineral Wells, confirmed the discovery of an important gas field in this locality. Subsequent drilling proved the productivity of the territory between the Hess and the Edmonson wells and attracted to the district the Doherty interests, which acquired in July a controlling interest in the new field that assures its efficient development.

In Stephens county, west of Palo Pinto county, and in Parker county, east of it, gas in fair volume was found in wells considerably in advance of the Strawn district and of the Edmonson-Hess area.

No new development took place in the Bangs gas field, in Brown county, in 1916, three wells supplying the fuel needs of some 85 consumers in the town of Bangs.

In Coleman county tests drilled for oil between Santa Ana and the old Trickham gas field in the southeastern part of the county furnished encouragement to the further quest for oil in the locality and added materially to the supply of natural gas available for field use and for consumption in Santa Ana.

Wells in the Reiser gas field in Webb county supplied, as in previous years, the natural gas consumed in Laredo. During 1916 a pipe line was constructed by the Border Gas company, from Laredo to the Jennings ranch gas field in northern Zapata county, 30 miles southeast of Laredo, and plans were completed for substituting gas from this source for that formerly obtained from the nearly exhausted Reiser field.

Six wells in the Crowther gas field, in McMullen county, supply natural gas to consumers in the town of Crowther. Ten other gas wells in this district are not in use.

In the Corpus Christi district, on the north side of Nueces Bay, in San Patricio county, little substantial progress was made in the development of the enormous resources of gas already proved to exist. On December 31, 1915, a gas well, the initial capacity of which was estimated in excess of 100,000,000 cubic feet of gas a day, blew itself in on the White Point lease of the Gulf Petroleum company, about 800 feet north of a similar well drilled in 1914. This well was completed the first week of January, 1916, but broke its heavy fittings on January 12 and ran wild for several days. On January 17 it caught fire and for nearly two months burned fiercely, forming about its mouth, as in the case of its predecessor, a seething crater of water, mud and burning gas that engulfed the remnants of the drilling rig and eventually choked the hole. The third well on this lease came in on July 16 with an estimated initial capacity of 20,000,000 cubic feet of gas a day, under a rock pressure of 600 pounds to the square inch. After blowing gas for several days this well was capped, and when opened later in July was found to have gone to salt water, barely enough gas being available for additional drilling in the locality. After running wild for more than a year well No. 1, of the Gulf Coast Oil and Gas company, on the Kirk tract, 2 miles east of the White Point wells, was finally brought under control and capped in December, 1916. Although a franchise was sought for supplying the gas from this well to the town of Corpus Christi, no active steps were taken toward marketing its product in 1916.

In practically all the oil fields in Texas more or less gas is used for drilling and pumping operations, and in various localities in the state, scattered wells, some of which are essentially water wells, furnish enough gas to satisfy the domestic requirements of one or more families each.

At the end of 1916 there were 257 gas wells in service in Texas, a net gain of 43 wells, or 20 per cent over the number in service at the end of 1915.

CONSUMPTION.

Aside from the natural gas piped into Texas from Louisiana for consumption in half a dozen towns adjacent to the state boundary, which is accounted for in the statistics for Louisiana, the volume of natural gas consumed in Texas in 1916 was equivalent to the volume produced, as no gas was piped from Texas to other states in that year.

Of the natural gas from intrastate sources consumed in Texas in 1916, some 5,423,295,000 cubic feet, or about 34 per cent, valued at $2,112,893, or 79 per cent of the total market value, was dis-

tributed to 68,218 domestic consumers at an average price of 38.96 cents per thousand cubic feet.

Compared with the statistics of natural gas consumption for domestic purposes in Texas in 1915 these data show gain in 1916 of 15 per cent in the number of consumers favored with natural gas service, of 10 per cent in the volume of gas consumed, of 14 per cent in the market value of the gas, and of 1.24 cents, or 3 per cent, in the unit price at which the gas was sold.

On the assumption that an average of 63,802 domestic consumers were supplied throughout the entire year, the average volume of gas consumed monthly by each consumer was about 7,100 cubic feet and the average monthly cost of natural gas service to each consumer was about $2.76.

The remaining 66 per cent of the Texas gas consumed in 1916, representing 21 per cent of the total market value, was distributed to 931 industrial consumers at an average price of 9.93 cents a thousand.

Compared with the statistics of natural-gas consumption for industrial purposes in Texas in 1915, these data show gain in 1916 of 35 per cent in the number of consumers, of 24 per cent in volume of gas consumed, of 40 per cent in the market value of the gas, and of 1.17 cents, or 13 per cent, in the average unit price at which the gas was sold.

RECORD OF NATURAL GAS INDUSTRY IN TEXAS, 1909-1916.

Year	No. Pdcrs.	No. Consumers Domestic	No. Consumers Industrial	Ttl. Val. of Gas Produced	Wells Drilled Gas	Wells Drilled Dry	Prod. Dec. 31
1909	17	5,035	130	$127,008	7	6	38
1910	19	14,719	133	447,275	22	5	52
1911	29	22,972	303	1,014,945	19	14	69
1912	41	27,226	329	1,405,077	24	23	87
1913	50	37,350	393	2,073,823	43	29	126
1914	75	48,547	468	2,469,770	89	23	197
1915	65	59,386	677	2,593,873	27	30	214
1916	83	68,218	931	3,143,871	77	113	257

Since 1916, the supply of gas in Kansas has decreased while the demand has increased so that there is a noticeable gas shortage in that state.

In Oklahoma, the supply from the Cushing field has fallen off with extreme rapidity and Blackwell has become the important gas producing pool. Osage county has furnished many good gas wells. In southern Oklahoma the Cement and Walter fields have been developed and the gas from the Loco field has been utilized.

In Texas, the new Burkburnett pool and the Ranger field have given some gas wells, and very large producers have been brought in in southeastern Eastland and northwestern Comanche counties.

A gas well reported at 5,000,000 daily capacity was brought in during 1918 north of Amarillo, and a good flow of gas is reported

from a well near Red river in Starr county. These wells may indicate important gas fields but both are far removed from the larger markets.

The rates for gas have risen somewhat but not in proportion to the increased cost of production. Some relief from this condition in Kansas was given by the granting of increased rates by certain cities but this matter is still in the courts.

CHAPTER IX.

ESTIMATION OF PETROLEUM RESERVES.

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VALUATION OF OIL PROPERTIES.

At the present time there is an increasing demand, on the part of owners and operators of oil properties, for detailed and thorough reports on the value of these properties. The necessity and importance of such information has long been realized, but until very recently there has never existed a general demand for the scientific valuation of oil properties. It was commonly supposed that any exact methods for determining the value of these properties existed only in the imagination of a small group of individuals who were willing to express themselves upon the subject, and these methods were generally neglected in favor of seemingly more practical methods, usually original with each individual and nothing more than each one's personal opinion.

It is true that inventories of supplies and apparatus for stocktaking or insurance purposes were very common, but valuations of oil properties, in the sense that the term is used at the present day as the basis of sale, capitalization or taxation were, until quite recently, very unusual.

At this time the need for such information has been called very forcibly to the attention of owners and operators, as a result of the Revenue Acts of 1916, 1917 and 1918, which levy a tax upon the net income received by individuals and corporations, engaged in the operation and development of petroleum properties. The amount of the income from these properties upon which this tax is levied is based upon a detailed report of the value of these properties as of a specified date. The preparation of these reports calls for information and data, the need for which has long been realized, but which for numerous reasons have rarely been recorded fully.

Even at present there exists no general practice nor well formulated theories for the valuation of petroleum properties. This is indicated by the generally confused state of mind of owners and operators, the divergent views of those engaged in the work, and the contradictory positions taken by the technical and so-called practical men as to the proper basis of valuing such properties.

It is not within the limits of this chapter to treat fully of the various methods used in evaluating petroleum properties. However, the most important, and yet, the most variable factor in reports on the value of these properties, is the estimate of the amount of oil or gas in reserve on these properties. A great amount of research work has been done by different men in an attempt to devise methods, by the use of which, it would be possible, within a reasonable limit of accuracy, to estimate the reserves, and much valuable information on this subject exists in various technical papers.

The purpose and intent of this chapter is to present the more general methods which have been suggested from time to time, briefly explaining their use and application, and summarizing the advantages and disadvantages of each method as they appear at present. None of the methods are original with the writer, although a considerable amount of work has been done along lines suggested by each of the various authors. In the following paragraphs an attempt has been made to give credit to the original investigators along these lines.

ESTIMATION OF PETROLEUM RESERVES.

There are two common, yet distinct, methods of estimating the reserve amounts of oil and gas, which are usually known as the "Saturation Method" and the "Production Curve Method."

Saturation Method.

The "Saturation Method" can be used in an attempt to estimate roughly the possible oil or gas content of any particular sand. Its most useful application is to that of areas which have not been drilled.*

This method involves the use of many factors, none of which can be directly determined with any degree of certainty. These factors stated in the order in which they are usually determined are:

(1) Volume of the productive formation that acts as a reservoir for the oil.

(2) The porosity of this formation, or the maximum volume of gasses and fluids that may be contained in a unit volume of the tormation.

(3) The relative saturation or the percentage of the porous spaces occupied by oil.

(4) The percentage of oil recoverable.

Of the above factors, the first, or the volume of the formation that acts as a reservoir, is capable of being determined more accurately than any of the others. In fields where the formations are fairly uniform in regard to thickness and lithology over extensive

*The "Saturation Method" is discussed in the following articles:
Washburne, C. W., Trans. A. I. M. E., 1915. P. 645.
Pack, F. W., Bull. A. I. M. E., No. 128, Aug. 1917.

areas, it is possible to determine the volume within reasonable limits of accuracy. This can be determined from measurements taken where the formation outcrops at the surface, and can be checked from data afforded by any wells within the area. However, in most of the fields the productive sands vary greatly as to thickness and lithology and any calculations by this method of the volume of the reservoir sands, when considered over extensive areas, will prove to be very unreliable.

In areas where a resonable degree of reliance can be placed on the calculations of the volume of the reservoir sands, it then be comes necessary to determine the porosity of these sands. The porosity factor is very difficult to determine, and will vary between wide limits from place to place throughout any one field. This variation is due to the local differences in the size of the grains, the shapes of the grains and the amount and nature of the cementing material in the reservoir rocks. The porosity of the productive sand as determined from samples obtained from drill holes will differ widely from that determined from samples taken at the outcrop. It is almost impossible to determine an average porosity for any given area, so an assumed value is generally taken for this factor.

In some fields, particularly those of Mexico, the storage capacity of reservoir sands is greatly increased by joints and fissures. The estimated volume of these joints and fissures must necessarily be purely speculative. Up to the present time no suitable method has been presented for estimating the reserves contained in joints, fissures, solution cavities, etc.

The relative saturation cannot be measured directly. Either the sand is figured as being totally saturated, or a value for the saturation factor is assumed, which is expressed in percentage of total saturation.

The above factors, either determined or assumed, when multiplied together will give a quantity which in a rough way represents the maximum amount of oil which is contained in the sand. However, with the present methods of extraction, it is not possible to recover this entire amount from the sands. It again becomes necessary to assume an extraction factor. This factor multiplied by the quantity of oil computed to be in the sand will give a resultant figure, which represents the amount of oil which can be recovered from the area.

As has been previously stated, the advantage of the saturation method is that it can be applied to areas which have not been tested. The disadvantage of the method lies in the fact that it involves, largely, the assumption of values for the various factors which enter into its use. However, for an area in which conditions are favorable, and by the use of conservative values for the various factors, it will give a rough estimate as to the maximum amount of oil which can

reasonably be expected from the area. Thus, the method has a value, in that it will tend to prevent excessive initial investment.

Production Curve Methods.

Where sufficient data are available, the production curve method, in some one of its many modified forms, is almost universally used at the present time in estimating future reserves. Although perhaps the simplest of all methods, yet, when sufficient data are available, it is generally conceded to be the most accurate and reliable method of estimating the future production of oil wells. Production curves plotted on various forms of co-ordinate paper are graphical representations of the production record of an individual well, a group of wells, a lease, a pool or an entire field. The ideal curve is that which can be compiled from the records of an individual well, however, as such data are seldom available it becomes necessary to use the production records of a group of wells and compile a curve which represents the performance of an *average* well of the group. "The underlying principle of the method is that *the best indication of the future production of any well is to be found in the history of similar wells in the same or similar districts*, and that, other things being equal, a well's production is more likely to approximate the production of a similar well in the tract or district than to deviate widely from the average."*

It is not necessary in the production curve method, as it is in the saturation method, to assume any values for any of the factors, which tend to influence production. The combined influence of these factors is automatically shown in the graphical record. From the records of past production of a well or property, the rate at which the production is declining can be computed. This rate of decline when plotted on co-ordinate paper tends to approach the form of a definite curve. The economic limit of the property is calculated from known conditions prevailing within the area, and the only problem now confronting the estimator is the extension of the curve, at the apparent rate of decline from the period of last recorded production to the economic limit of the property.

The better policy is to construct decline curves of each property. This is done by plotting the average daily output per well, that is the total production of the property divided by the number of wells producing during each time period. If all the wells on the property were completed at approximately the same time this curve would show the decline in production of the property, and by properly extending this curve, one could obtain for each property, an estimate of the future reserve, which would be based upon the past records of each particular property. However, this is not possible as it

*Manual for the Oil and Gas Industry, U. S. Bureau of Internal Revenue, page 27, 1919.

is very seldom that all of the wells on a property are drilled at approximately the same time. The effect of the initial flush production of new wells drilled from time to time is to retard the rate of decline for the property.

It is impossible to construct for each property, a decline curve, which would furnish sufficient basis for estimating the reserve, until the property has produced for three or four years. However, it is often desirable to know the amount of oil in reserve on a property before it has produced for a period of time sufficient to plot a decline curve of the particular property itself. In this event, it becomes necessary to use the decline curves of adjoining properties, a general decline curve of the area in which the property is located, or the decline curve of a similar property in a similar district.

General decline curves of a district, pool or field, are compiled by averaging the values taken from the curves of a number of representative properties within the area. Great care must be exercised in the selection of properties to be used in compiling a general decline curve of a district, in order that the effect of deferred drilling will be a minimum.

In a number of cases it is impossible to secure the data necessary to plot decline curves, or figure the rate of depletion of an oil property. Very often, due to indifference or neglect, the necessary data were never properly recorded or filed, and consequently portions of the production records of a property became lost. The accompanying table or production record illustrates a simple method of recording production data of a property. The production of each lease is totaled every month and recorded on a card maintained for that particular property. The numbers above the heavy black line show the production, and number of wells producing for each month throughout the various years. The numbers below the heavy black line are computed from the recorded production data, and are the values used in plotting production curves. On the reverse side of the card, one side of which is shown in the table, is recorded the data necessary for filing and indexing, such as locations and description of the lease, names of lessee and lessor, and a plat showing the lease with the location and the number of all wells on the property. Spaces are provided for remarks as to depth, thickness and general conditions of sand, gravity of the oil, water conditions, average initial production, estimated reserve, etc. In this manner, a complete history of each lease is assembled and recorded on one card, and all of the data relative to any one property are available in a moment's notice.

PRODUCTION RECORD.

	1905	1906	1907	1908	1909	1910	1911	1912	1913	1914	1915	1916	1917
JANUARY		4360	3807	1906	1406	460	504	191	146	146	68		
Wells Producing		5	6	6	6	6	6	6	6	6	6		
FEBRUARY		2669	2979	1471	468	937	85	192	145	146			
Wells Producing		5	6	6	6	6	6	6	6	6	6		
MARCH		2372	4021	1430	1106	481	819	245	194	25	74		
Wells Producing		5	6	6	6	6	6	6	6	6	6		
APRIL		3608	2385	2421	945	944	351	144	195	72	73		
Wells Producing		5	6	6	6	6	6	6	6	6	6		
MAY		5927	2800	1397	910	482	358	286	143	73	73		
Wells Producing		6	6	6	6	6	6	6	6	6	6		
JUNE		5589	3080	1827	491	484	570	194	195	73			
Wells Producing		6	6	6	6	6	6	6	6	6	6		
JULY		4361	2155	1838	469	480	250	190	147	72	73		
Wells Producing		6	6	6	6	6	6	6	6	6	6		
AUGUST		3853	2500	973	967	483	346	246	145	143	71		
Wells Producing		6	6	6	6	6	6	6	6	6	6		
SEPTEMBER		2900	2383	944	1424	476	358	141	142	159			
Wells Producing		6	6	6	6	6	6	6	6	6	6		
OCTOBER	452	4634	1840	908	959	753	283	196	143	62	73		
Wells Producing	1	6	6	6	6	6	6	6	6	6	6		
NOVEMBER	2142	2933	2353	933	949	162	359	243	98	17			
Wells Producing	3	6	6	6	6	6	6	6	6	6	6		
DECEMBER	2794	3654	1415	955	937	905	239	194	143	73	73		
Wells Producing	4	6	6	6	6	6	6	6	6	6	6		
Total Production	5388	46860	31718	17003	11031	7047	4522	2462	1836	1061	578	218	
Total Wells	8	68	72	72	72	72	72	72	72	72	72	72	
Average Wells	2.7	5.7	6	6	6	6	6	6	6	6	6	6	
Yearly Prod. per well	1996	8221	5286	2834	1839	1175	754	410	306	177	96	36	
Average Well per Day	21.7	22.5	14.5	7.8	5.0	3.2	2.1	1.1	.8	.5	.3	.1	
Average Prod. per Acre													
Per Cent Decline		100.	64.4	34.7	22.2	14.2	9.3	4.9	3.6	2.2	1.3	.4	
Per Cent, Cumulative		100.	168	204	227	242	252	257	261	264	265		

AVERAGE PER WELL PER DAY THROUGHOUT ENTIRE PERIOD, 6.6.

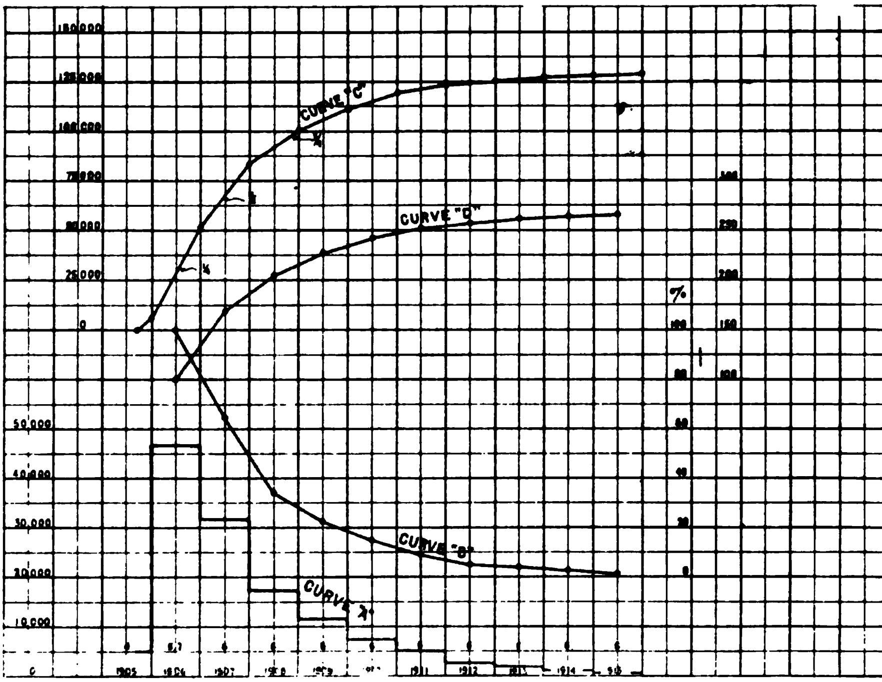

Fig. 95.—Production graphs. (decline curves.)
A. Actual production, barrels per year; B. Percent decline curve; C. Total accumulation curve; D. Percent accumulation curve.

In fig. 95 are shown some production curves, which were plotted from values as shown by the data below the heavy black line in the table. Curve "A" shows graphically the total yearly production and portrays a vivid comparison of the total production from the property from one year to another. In all of these curves the time factor, herein taken as yearly periods, is plotted horizontally and shown at the bottom of the curves. Just above these latter figures are those indicating the average number of wells producing throughout each year. The production scales in terms of barrels are shown on the left, while the scales of percentages are shown on the right. Curve "B" indicates the decline, in barrels per average well per day, expressed in terms of percentage of the first year's production. It must be emphasized that this curve represents the decline of an *average* well on the property and that the decline is expressed in terms of *percent* of the production for the first year.

Percentage values are used in plotting this curve as well as curve "D" above, to allow a ready comparison of this property with any other in the same, or another district. Also it enables one to compile and plot a composite decline curve of the entire district by

averaging the decline curves of the representative properties within the area.

If the production records for the first few years of any given property are available, the percent decline values can be computed, and the curve "B" plotted for the period covered by past production records. This curve is then extended at the apparent rate of decline, until the economic limit of the property is reached. Having extended the curve the estimator can now compute within narrow limits, not only the total amount of oil which can be expected in the future, but also the rate of future production, or the amount which will be produced in any given year in the future.

After decline curves are plotted for several properties in any given pool or field, the values of these curves may be averaged, and a general curve drawn for the entire pool or field. This curve then represents the decline of an average well in the pool or field. Having given the general decline curves for several fields, comparisons can be made, also a study of the factors which influence production in each field.

Curve "C" (fig. 95) is the cumulative production graph showing the total amount of oil produced from the property at the close of any time period. The fractional figures on this curve indicate the time required to produce these fractional parts of the total amount of oil which may be expected to be produced. That is, one-fourth of the total amount to be produced from the property was obtained in the first eleven months of the life of the property, one-half of the total amount in the first eighteen months, etc.

Curve "D" (fig. 95) is the cumulative percent graph. In this curve the cumulative production values are expressed in terms of percent of the first year's production. The ultimate percent of this property is shown to be 265 percent, i. e., the total amount of oil produced from the property is 2.65 times the production of the first full year.

Another form of the production curve method is very often used and consists of drawing a curve showing the total production from the entire field per unit of time. Points on this cure are considered and the decline represented. This curve is then projected and an estimate is made of the future production. The objection to this method is that it assumes that new wells will continue to be drilled up to the time that the pool is drained.

A slight modification of this method is to compute the decline of the entire field and also the rate of development. It is then assumed that this rate of development and rate of decline will continue until the field has been completely drilled. After the field has been completely drilled the decline will be more rapid, due to the fact that there will be no new wells, the effect of which is to retard the rate of decline of the field.

Although many of the factors entering into this method vary greatly, some very good results have been attained by the use of it, and with careful consideration and study of the various factors. some close estimates can be made.

At the present time the production curve method is conceded to be the most practical method for estimating future reserves. One objection to the method is that it requires considerable time and care in collecting and filing the necessary data. Also that the curves cannot be constructed until the property has produced for several years. However, with sufficient data at hand, and a careful study of the factors which influence production, the decline curves of one property may be applied to another property producing under similar conditions.

Production Per Acre Method.

This method is very often used in estimating the reserves on properties which are only partially developed. The production curve method is used to estimate the reserve on the developed acreage. The ultimate production of the developed acreage is then reduced to the amount of oil produced per acre. The decline in acre yield is then computed and this quantity applied to the undrilled acreage. Fairly accurate estimates can be made by the use of this method, although considerable judgment must be exercised in its application.

* * * * * * * * * * * *

Oil wells usually reach their maximum daily output shortly after they are completed. From that time they decline in production, the rapidity of the decline depending on the output of the wells and on other factors governing their productivity. The factors tending to influence the decline of oil wells are many. The effects of some are very great and are a basis for much consideration and study. The effects of others are almost negligible. It is only by a close study of the effects of these various factors as they influence production, and incorporating these effects into the various decline curves, that accurate results can be expected in the estimating of future production from oil properties.

Very often it becomes necessary to make a rough estimate of the value of a property located in a new pool or field, but in territory wherein the limits of production have been fairly well defined by several producing wells and dry holes. In such instances the production data do not furnish an adequate basis for the construction of decline curves, and projecting them within a reasonable degree of accuracy.

Although important data are lacking, by careful study and comparison it is possible to make a fairly accurate estimate. The best indication of future production from wells in the new field will be found by a comparison with the past records of wells in a similar district. This comparison requires careful study, and a

consideration of all the various factors which tend to effect the rate and ultimate amount of production.

Future production from the new field can be estimated by computing the ultimate production of individual wells. However, this usually necessitates the estimating of initial productions, which in turn are dependent upon the time of drilling and a number of other factors. This procedure greatly increases the limits of possible errors. A more accurate estimate of future production can be made by computing acre yields in an oil field, and the application of these acre yields with the necessary modifications to the new field.

Estimates of future reserves, as well as values of properties, in new fields are often changed very quickly. The change may be an increase or a decrease, dependent upon such influences as the completion of certain test wells, unforeseen calamities such as sudden water flooding, etc. Although the reserve has been estimated very accurately values are subject to great change owing to sudden variations in the price of oil. Therefore, estimated values given by the engineer are necessarily values existing at the particular time the estimate is made. However, they should include statements as to the indication of the future action of wells, and conditions effecting supply and demand, and the future prices of oil.

Though necessarily inaccurate, these estimates of the value of properties in new fields have a distinct value in that they summarize existing knowledge of similar conditions in other fields. They also enable persons who are interested to formulate rational commercial policies, and tend to prevent undue and excessive initial investment.

As was stated in the forepart of this article, the estimation of reserves is only one of the many items entering into a report on the valuation of oil properties. However, of all the items it is, without a doubt, the most important, and considerable research work remains to be done in devising methods which can be used to estimate, quickly and accurately the future production of oil properties.

Naturally, geologists and engineers have been called upon to estimate and determine the values of oil properties. The determination of the value of the intangible property, as well as the physical value is essentially a geological problem, because geologists and engineers with the proper experience and qualifications are best informed, not only as to structural conditions and other factors influencing the accumulation of petroleum, but also as to the expenses involved in getting a property started and building up an income producing business.

This new and larger field of valuation work, however, has put new responsibilities upon the geological profession, demanding something more in the way of a knowledge of the various factors which influence production, also a knowledge of values and questions of law and economics.

CHAPTER X.

THE NATURAL-GAS GASOLINE INDUSTRY.

By S. E. MURPHY

Manager Empire Gasoline Company.

GENERAL AND HISTORICAL.

Coincident with the wonderful development of the automobile industry and the enormous demand for motor fuel resulting from it, there also has been a remarkable development in the petroleum industry to meet the burden of the ever growing demand for a suitable motor fuel.

At the present time the two main sources of gasoline motor fuel are petroleum and natural gas. Until within recent year comparatively speaking, gasoline in this country was produced almost entirely by the refining or distillation of petroleum. This condition existed until approximately 1907 when the demand for gasoline began to increase, and with the increasing demand there was subsequently created a better market and price for the product. Until this demand was created by the widespread use of the automobile and the internal combustion motor, gasoline was practically considered of little commercial value, and it has been reported that in some instances was disposed of by the refineries as refuse. At this period in the refining industry, lamp oil and lubricants were in demand, and the refinery operations were conducted principally for the production of these two products.

Early in the history of the production of petroleum the men who were identified with the field work noticed the accumulation of a condensate in the gas lines from both oil and gas wells, and the remarkable similarity of the condensate and gasoline. However. no marked attention was given to the condensate then as there was no known method of using it. Later, however, when the demand and price for gasoline started upwards, attention was turned to the recovery and utilization of the condensate, or as we now call it, drip gasoline, which rapidly resulted in the development of the natural-gas gasoline industry.

Table No. 1 will show the progress made by the industry from year to year. Records show but one plant in operation in 1904 but in 1911 there were 176 plants. Each year since then has shown a material increase in both plants and production.

(Table No. 1)

NATURAL GAS GASOLINE MARKETED IN U. S., 1904-1917

Year	Number of Operating Plants	Gallons of Gasoline Produced	Per Cent Gasoline Gained Over Previous Year	Cubic Feet Gas Used To Produce Total Gallons Gasoline	Average Price Cents Per Gallon Gasoline	Value of Gasoline in Dollars	Gallons Gasoline Per 1,000 Cubic Feet Gas
1904	1	4,000			10.0	400	
1911	176	7,425,839					
1912	250	12,081,179	63	4,687,796,326			2.600
1913	341	24,060,817	100	9,899,441,500	10.22	2,458,443	2.430
1914	386	42,652,000	77	16,894,557,000	7.28	3,105,909	2,510
1916	596	103,492,689	59	24,064,391,000	7.88	1,202,555	2.570
1916	594	104,212,809	59	208,705,023,000	13.85	14,331,148	0.496
1917	886	217,884,104	11[illegible]	429,197,797,000	18.45	40,188,956	0,508

(Table No. 2)

CLASSIFICATION OF PRODUCTION OF NATURAL GAS GASOLINE IN 1917 BY PRINCIPAL METHODS OF MANUFACTURE

Gasoline Produced by Compression and by Vacuum Pumps.

State	PLANTS Number	Daily Capacity in Thousands	GASOLINE PRODUCED Quantity in Gallons	Value	Price per Gallon	GAS USED Estimated Volume Gas Treated Annually In Thousands	Average Yield of Gasoline per M. Cu. Ft.
Oklahoma	207	456,632	108,728,213	$20,321,067	18.68	36,399,280	2.987
California	40	82,092	23,478,521	3.637,827	15.49	27,477,443	0.854
West Virginia	159	44,348	12,276,784	2,211,494	18.01	4,845,648	2.534
Pennsylvania	234	32,564	9,011,199	1,792,430	19.89	3,572,356	2.522
Louisiana	18	17,915	4,459,920	719,758	16.14	1,558,346	2,862
Illinois	54	15,392	4,268,158	756,344	17.72	2,020,044	2.113
Texas	8	10,900	3,942,337	664.543	16.86	2,666.983	1.478
Ohio	54	8,337	2,331,498	423.106	18.15	836,639	2.787
N. Y. 5; Kan. 1; Ky. 3; Col. 1	10	3,322	369,925	70,36[illegible]	19.02	150,784	2,453
Total	784	671,502	168,866,555	$30,596,930	18.12	79,527,523	2,123
		GASOLINE PRODUCED BY ABSORPTION (a)					
West Virginia	29	91,315	20,391,863	$ 4,300,319	21.09	162,925,703	0.125
Oklahoma	27	35,804	6,395,211	1,220,838	19.09	48,320,661	0.132
California	9	17,669	5,339,083	800,195	14.99	17,873,804	0.299
Pennsylvania	17	26,600	4,815,051	985,668	20.47	45,914.700	0.105
Kentucky (a)	2	13 000(b)	3,725.893	745,210	20.00	24,871,590	0.150
Ohio	7	16,800	3,108,062	628.270	20.21	29,255,522	0,106
Texas (c)	3	21,650	2,978,068	484,898	16.28	10,010,233	0.298
Kansas	5	3,842	1,071,633	220,550	20.58	9,274,289	0.116
Illinois (a)	1	2,000	665,851	109,689	16.47	665,851	1.000
Louisiana (a)	2	2,203	519,834	94,989	18.27	675,165	0.770
New York (d)			7,000	1,400	20.00	2,776	
Colorado							
Total	102	230.883	49,017,549	$ 9,592,026	19.57	349,760,284	0.140
Grand Total	886	902,835	217,884,104	$40,188,956	18.45	429,287,797	0.508

(a) Includes drip gasoline. (b) Includes gasoline produced in Kentucky from West Virginia gas. (c) Includes some gasoline produced by compression. (d) Drips only.

The year 1917 has shown the most remarkable development in both value and gallonage. The accompanying table (No. 2), compiled by J. D. Northup, of the United States Geological Survey, Department of the interior, shows the production by states, and also the amounts produced by the compression and absorption processes.

While table No. 2 shows the value of the year's production to be $40,188,956, it reflects only a small portion of its true economic value. Natural gas gasoline as it is produed cannot be used efficiently for motor fuel, owing to certain inherent characteristics. However, it is mixed, or rather blended, with a refinery product which is usually too low in grade to be marketed as gasoline or motor fuel. The two products are mixed in approximately equal proportions, and when properly blended make an ideal motor fuel. Based on the above blending proportions the natural gas gasoline industry added 435,704,208 gallons of motor fuel to the supply of that product for 1917.

While the relative increase in production for 1918 is not expected to be as large as the increase of 1917 over 1916, it will show a marked advance both in quantity and also in value.

Naturally this additional supply of motor fuel has had an effect on the price of it, keeping it at a level in this country which never restricted the use of the automobile. It was also an immense value to the Allies, enabling them to secure not only the quantity to meet their requirements, but also the quality which was of especial importance in the aviation fuel requirements.

PROCESSES OF MANUFACTURE.

Natural-gas gasoline is produced by two processes—absorption and compression—and the product is generally spoken of as absorption or compression gasoline. The gas treated is usually classified as a wet gas or a casinghead gas, which comes from a well producing oil, or as dry gas, which comes principally from a well producing gas only. However, there are exceptions to this classification. Gas having a gasoline content higher than one gallon per thousand cubic feet, is spoken of as a wet gas, while that having a content less than one gallon is spoken of as dry or lean gas. At the present time dry gas has only been treated on a commercial basis by the absorption process. The majority of the plants treating wet gas are of the compression type, although the absorption process can be operated with excellent results on wet gas also, especially so on large quantities.

Compression Method.

The compression-type plant generally draws its gas supply from the oil wells by the utilization of suction or vacuum pumps. By securing the gas supply in this manner the vapor pressure on the oil

sands is reduced and a larger amount of hydrocarbon or gasoline vapors are released from the oil sand than could be by taking the gas from the well at its normal pressure. After coming from the field the gas passes through a trap or settling chamber to free it from any foreign matter such as scale, sand, water or oil. It is then metered and then goes into a low stage compressor where it is compressed to about fifty pounds gauge pressure. From here it passes through a pipe coil sprayed by water and then it passes into an accumulator tank. Any condensate that has been formed falls to the bottom of the tank. The gas passes back to the high stage compressor where its pressure is raised to about 250 pounds, and from here discharges at the same pressure into another series of water cooled coils and then into another accumulator tank where additional condensate is collected. In the average plant the condensate is then mixed with naphtha or distillate and is ready for shipment to the refinery where it is made into a finished motor fuel. The flow sheet for such a plant is shown in fig. 96.

The larger and more efficient compression plants, however, go farther in their operation than that outlined above. They take the gas as it leaves the high stage accumulator and subject it to a low temperature secured by expansion or refrigeration and extract additional condensate; in some cases the increased recovery amounts to 15 per cent. After the gasoline has been extracted the gas is then used for fuel to operate the plant and the oil lease. If there is an excess it is generally sold to a gas company.

A few of the very large installations of the compressor method in Oklahoma handle the gas gathered from a thousand wells or more, and have gas engine power which runs up as high as 2,000 power. There are many plants throughout the country, however, operating successfully whose power requirements run less than 100 horse-power.

Principles of Compression.

Casinghead gasoline consists of various members of the methane group of hydrocarbons, especially butane, pentane and hexane. Butane at atmospheric pressure boils at 33 degrees F., pentane at 97 degrees F., and hexane at 156 degrees F. Small amounts of heptane, octane and even higher fractions are also present in small quantities.

The pressure necessary to condense the gasoline vapors or fractions present in casinghead gasoline, depends entirely on the proportion of each to the amount of non-condensable gas present. To understand this, it is necessary to understand the "'Law of Partial

Pressures," which states that "Every portion of the mass of a gas in a vessel contributes to the pressure against the sides of the vessel the same amount it would have exerted, had no other gas been present."

For example, air contains approximately 20 percent oxygen and 80 percent nitrogen, and exerts a pressure of 14.4 pounds per

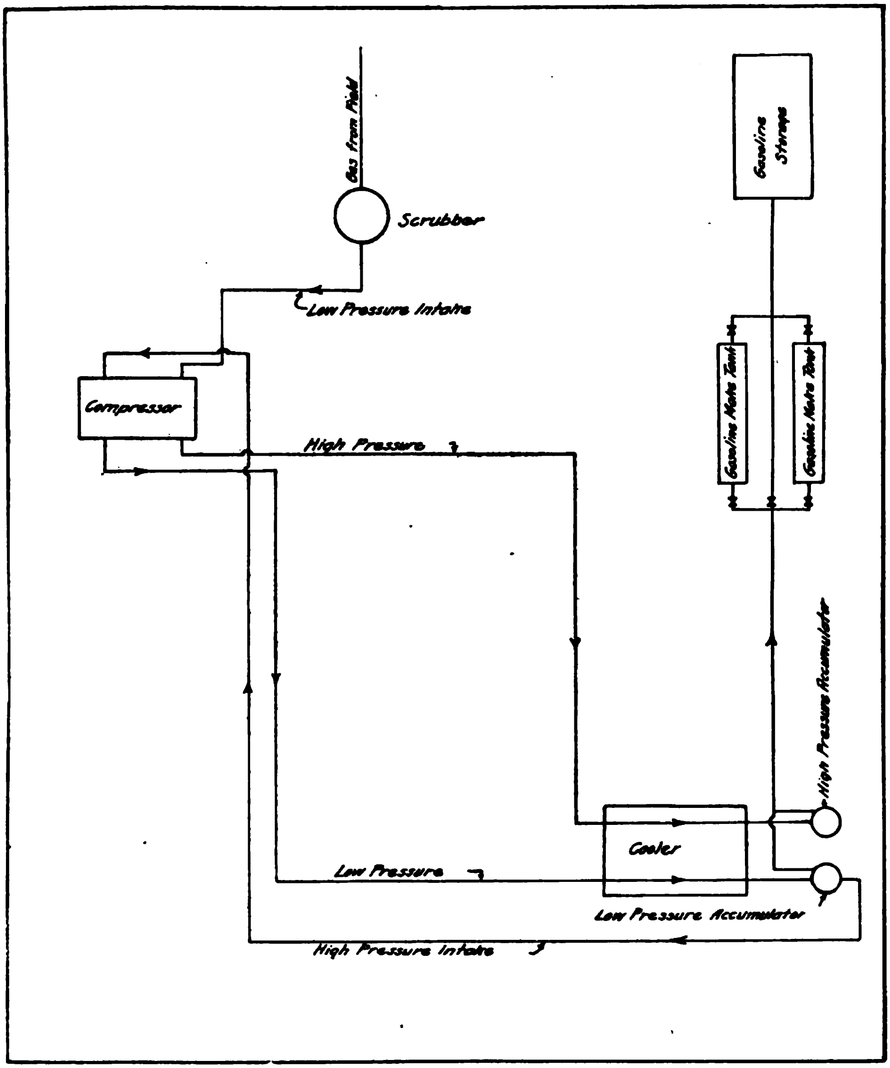

Fig. 96—Flow sheet for compression type gasoline plant.

square inch. Of this pressure, 20 percent or 2.88 pounds is exerted by the oxygen and 80 percent or 11.52 pounds by the nitrogen. Butane at a temperature of 59 degrees F. condenses at 33 pounds per square inch in pressure. In a mixture of equal parts of methane, which is non-condensible, and butane at 59 degrees and under a pressure of 33 pounds per square inch each would be under a pressure of 16½ pounds. Since 33 pounds is needed to condense butane no liquid would be obtained. However, increase the pressure of the mixture to 66 pounds per square inch each part would be under a pressure of 33 pounds and the butane would condense. Following out this reasoning a mixture containing 10 per cent butane would require a pressure of 330 pounds per square inch to condense the butane. And since the partial pressure acting on the remainder would become less as a portion condensed, it would be impossible to liquify all the butane present under pressures economically possible in ordinary plant operation.

Cases have arisen where plant production was materially decreased by the addition of a dry gas, or one containing few condensable vapors. In one instance the production dropped to almost nothing, returning to normal when the dry gas was shut out. The explanation is found in the law stated above. The added noncondensable vapors decreased the partial pressure acting on the gasoline factions to a point below that necessary for condensation. Consequently they passed through the cycle as gas and were lost.

Absorption Process.

The absorption process is used principally to treat natural gas as it is transported in large quantities from the gas fields by pipelines for domestic and manufacturing purposes. The process is similar to that used in a by-product coke plant for the extraction of light oil from which benzine and toluene are made, from the gas produced by distillation of coal. The principal difference in the two processes is that the natural gas is generally treated under high pressure (owing to transportation requirements) while the coal gas is treated under comparatively low pressures.

The following paragraphs will be devoted to a brief description of the absorption process, with particular reference to the handling of the natural gas, the absorbent oil and the gasoline vapors.

The absorbers are usually arranged in parallel, on a by-pass from the main gas line, so that the full amount of gas is equally divided and passed through any number of absorbers. The gas enters near the bottom of the absorber, which is made in various sizes and designs, usually about thirty inches in diameter and thirty to forty feet

in height. The gas is taken out near the top of the absorbers and brought again in the outlet gas header.

The oil is pumped into the absorbers near the top and just below the gas outlet. The oil then falls down through the absorber counter-current to the flow of gas, over loose porous baffle material such as chemical tile, metal shearlings, or wood lattice. The object of the baffle is to spread the down flowing oil in thin films, and present the most intimate and thorough contact possible with the upward flowing gas. It is during this contact that the gasoline vapors are absorbed from the gas by the absorbent oil. The enriched or treated oil collects in the bottom of the absorber and is then automatically trapped to the weathering tank under reduced pressure.

The weathering tank is usually a cylindrical tank of about 5,000 gallons capacity, the function of which is to free the enriched oil from non-condensable gases, such as methane and ethane, most of which comes from the absorbers mechanically mixed with the oil. This gas is usually carried away under about two pounds pressure and used for fuel under the boilers. The weathering tank also serves as a water separator to collect any salt water which may be carried over from the gas line, and also water which becomes mixed with the oil in the process of distilling.

From the weathering tank the oil is picked up by the low pressure pumps, which force it through a heat interchanger and into the top of a regenerator tower, both of which will be described at a later point.

The oil gravitates from the regenerator tower into the still which is really nothing more than a tank, usually of about twelve thousand gallons capacity. It is equipped with steam pipes for introducing either live or exhaust steam, directly or indirectly or both, for the purposes of heating the absorbent oil to the temperature at which the gasoline vapors are given off. The stills are usually carried at about 212 degrees F. and under a pressure of one to three pounds. Usually the exhaust steam from the oil pumps and compressor is sufficient for treating purposes in the still. The still is equipped with baffle walls, so placed that the enriched oil which enters at one end, is almost entirely freed of its gasoline content by the time it flows to the opposite end, where it is removed by the high pressure pump suction.

The high pressure pumps discharge the hot oil through the heat interchanger, counter-current to the cold enriched oil which is coming from the absorbers to the still.

The interchanger is made in various designs, usually a series of small pipes or tubes which carry the cold oil, surrounded by an outer shell which carries the hot oil. The heat interchange takes place through the walls of the smaller inside tubes. The interchanger is primarily a heat saving device, and as such, the average

gasoline plant interchanger effects a saving of from twenty to thirty percent of the total boiler horsepower of the plant. It also acts as a cooling device for the outgoing hot oil, which for efficient operation must be cooled to about 80 degrees F. before it is again introduced into the absorbers. The necessary cooling, which is not accomplished in the interchanger, is later done by water cooled coils. It may be roughly stated that if no interchanger is used for cooling the oil, that about twice as much cooling surface in the oil-cooling coils must be provided, to bring the oil down to the necessary low temperature.

After leaving the interchanger, the oil passes to the oil cooling coils, which are usually made of two-inch pipe connected in parallel and placed in an aerial cooling tower. The tower is so designed that the water falls over the coils in fine drops, or spray. A double cooling effect is produced, first by the actual contact of the cold water and hot pipes, and secondly, by the evaporation which takes place as the thin film of water passes over the hot pipes.

The oil cycle is completed when the oil leaves the oil-cooling coils and enters the absorbers again, the same absorbent oil being used over and over again with small loss.

The gasoline vapor cycle begins with the still, where a mixture of water vapor, gasoline vapor, and a small amount of mineral seal oil passes from the still and enters the regenerator tower near the bottom. The regenerator tower is very similar in design to an absorber, except that it is usually not over twenty-five feet in height and is set at such an elevation that oil will gravitate from its base into the still. The enriched or incoming oil is introduced near the top and flows downward over the baffle material in the opposite direction to the flow of vapors which are taken off near the top.

The regenerator tower performs several functions. The hot vapors coming in contact with the enriched oil extracts some of the gasoline from it while passing through the tower. There is also an interchange of heat between the vapor and the enriched oil, which is beneficial to both. Also considerable water vapor is condensed which flows back into the still and is drained off through the water drain.

After leaving the regenerator tower the vapors enter the auxiliary condenser or knock out box, where the vapors are cooled to 170 degrees to 180 degrees F. by means of coils submerged in water, or by spraying cold water directly into the vapor. At this temperature practically all of the mineral seal oil is condensed and most of the water vapor, which is then trapped off through an oil and water separator.

The vapor then passes to the main condenser box, where the gas is passed through coils submerged in water, and the temperature of the vapor lowered to a point where the gasoline vapor

condenses. The amount of gasoline condensed in the main condenser depends upon the size and design of the coils and the temperature of the water available for cooling purposes.

The remaining gasoline vapor is then passed through a set of vapor cooling coils, usually two-inch pipe arranged in parallel, and placed either in the same aerial cooling tower as the oil coils, or in a separate one. In some plant designs the aerial cooling coils are omitted and all of the condensation accomplished in the main condenser box, but this is only advisable where an unlimited supply of cold water is available. The more common practice, especially where the water supply is limited, is to omit the main condenser box and do all of the vapor cooling in the water sprayed coils in the aerial cooling tower. This is undoubtedly the most efficient method of cooling.

From the main condenser box and the water sprayed coils, the condenser gasoline along with the remaining uncondensed gasoline vapor is gravitated to the look boxes in the receiving or tail house. From the look box the gasoline, called the straight absorption product, is gravitated or pumped to storage.

Just as the gasoline is entering the look boxes the remaining gasoline vapors are collected in a tail-gas header, from which the suction to a compressor is taken. The remaining vapors are the higher hydro-carbons, which are not condensable at 70 degrees to 80 degrees F, atmospheric pressure. This vapor, however, when passed through the compressor and discharged at from one hundred to one hundred and fifty pounds pressure and again passed through water sprayed coils, is almost entirely condensed. This condensate with the remaining gasoline vapors are then piped into the bottom of the naphtha blending tower. This tower is similar in design to the absorbers, except that it is much smaller in size, usually about sixteen-inch pipe and twenty feet high. Naphtha is pumped into the tower near the top, and in passing downward over the baffle material counter-flow to the gasoline vapors, absorbs them almost completely. At the top of the tower is a relief valve set at one hundred and fifty to two hundred pounds, which opens only when the tower becomes filled with vapors or air which cannot be absorbed in naptha. Ordinarily this valve pops off only a few minutes during the day as all of the gasoline vapors which were originally absorbed by mineral seal oil are readily absorbed by naphtha.

The blended mixture, the gravity of which is controlled by the amount of naphtha used, collects in the bottom of the tower and is then trapped to storage, and is known as the blended or compression product.

The process may be summarized as follows: The gas is introduced into an absorber or scrubber where it is brought into contact with a mineral oil having a high boiling range. As the gas passes through the oil the gasoline vapors are absorbed from it by the oil. The oil is then pumped into a receiving tank and from here it is taken into a still carried at an approximate temperature of 212 degrees F. The temperature should be sufficient to release the

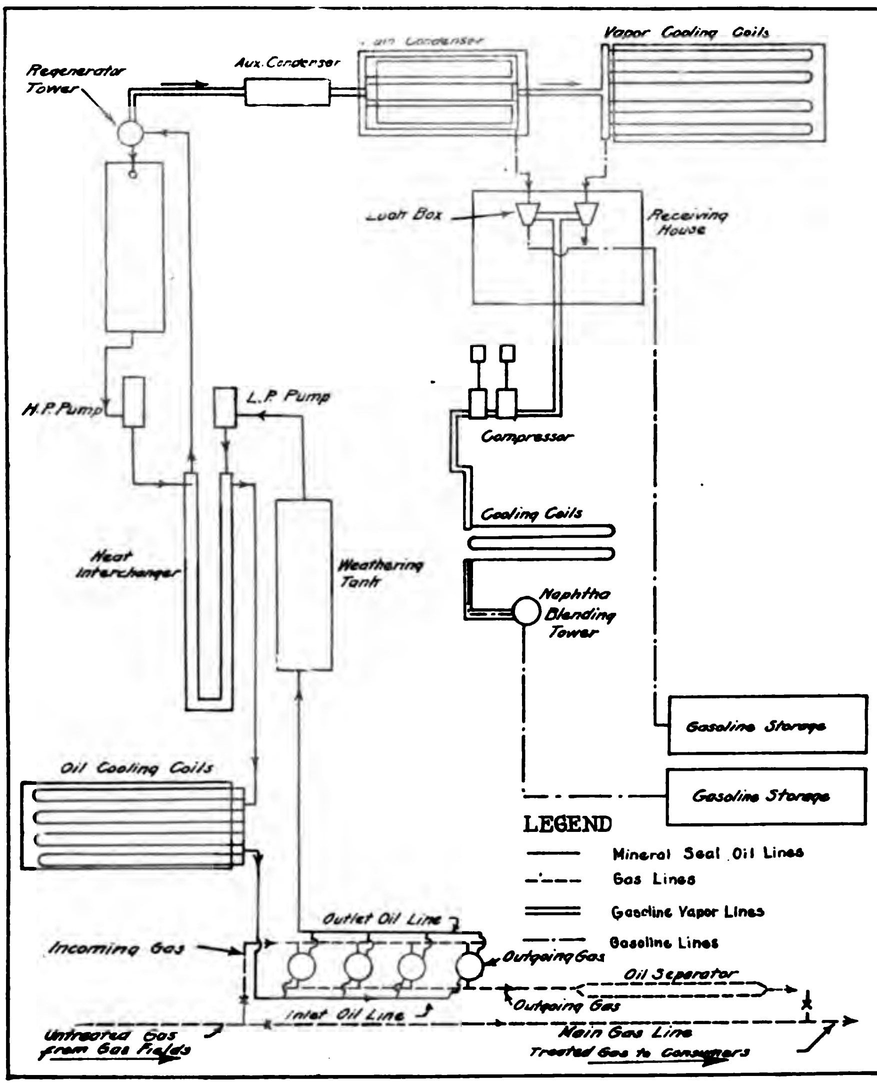

Fig. 97—The flow sheet of casinghead gasoline plant. Compression type.

gasoline vapors from the oil, but not high enough to distill any of the absorbing oil over with the gasoline vapors. The vapors are conducted through pipe coils cooled by water at a temperature which causes the condensation of the vapors into a liquid. Vapors that do not condense here are subjected to a process very similar to the compression process described in this article. After the gasoline vapors are driven from the oil by the heat maintained in the still, the denuded hot oil then passes through a heat exchanger where it gives off some of its heat to the incoming oil to the still, and then passed through the cooling coils and is then ready to be passed through the absorbers again. The process is continuous, the same oil being used repeatedly.

The flow sheet for an absorption-type gasoline plant is shown in fig. 7.

The absorption gasoline plant has been a great assistance to gas companies, not only from the profit which may be made by the sale of the gasoline extracted, but also from the better condition of the pipelines resulting from the extraction of gasoline and water vapors Large gas lines frequently have at each joint a coupler with rubber gaskets. Gasoline deteriorates the rubber very quickly. The resulting increase in the life of the rubber gasket has cut down pipeline repairs, saved gas and also service interruption. The extraction of water vapors has also cut down the freezing to a minimum in the winter time.

* * * * * * * * * * * *

The United States Bureau of Mines have devoted a great deal of study to the production of natural-gas gasoline, and have issued several bulletins and technical papers on the subject. For reference see the following publications of that bureau:

Bulletin 120. Extraction of Gasoline from Natural Gas by Absorption Methods.

Bulletin 151. Recovery of Gasoline from Natural-Gas by Compression and refrigeration.

Technical Paper No. 10 Sequinfied Products from Natural Gas.

Technical Paper No. 11 (209) Traps for Saving Gas at Oil Wells.

Westcott's Hand-Book on Casinghead Gas, also gives considerable information concerning the industry.

APPENDIX

Well Logs
Refineries
Pine Lines

WELL LOGS.

In the following pages are grouped well logs which are believed to be characteristic of the different pools which have been described. No attempt has been made to correlate the formations shown in these logs but they are thought worthy of including since they show the depth and thickness of the producing sands and the character of the rocks encountered in drilling. Not all the pools are represented by logs but a sufficient number are given to represent the principal producing districts.

The logs have been collected from many sources, many have been published previously, while others are published for the first time.

KANSAS

FRANKLIN COUNTY.

LOG OF WELL A. D. CARTZDAFNER No. 1, SEC. 10-18-21.

Formation	Thickness Feet	Depth Feet	Formation	Thickness Feet	Depth Feet
Soil	10	10	Lime	10	590
Lime	15	25	Shale	5	595
Shale	35	60	Lime	10	605
Lime	25	85	Shale	5	610
Shale	80	165	Lime	5	615
Lime	35	200	Shale	5	620
Shale	15	215	Lime	3	623
Lime	5	220	Shale	10	633
Shale	40	260	Lime	10	643
Lime	15	275	Shale	69	712
Shale	5	280	Sand	10	722
Lime	35	315	Shale	24	746
Shale	5	320	Sand—Gas and Oil	27	773
Lime	25	345	Shale-Sandy	5	778
Shale	5	350	Sand	32	810
Lime	25	375	Sand-Water	40	850
Shale	130	505	Shale	105	955
Lime	25	530	Sand-Water	10	965
Shale	5	535	Shale	57	1022
Lime	10	545	Lime Mississippian	10	1032
Shale	35	580			

LOG OF WELL J. R. RODGERS No. 1, SEC. 19-17-21.

Formation	Thickness Feet	Depth Feet	Formation	Thickness Feet	Depth Feet
Soil	20	20	Shale	35	505
Lime	22	42	Lime	10	515
Shale	83	125	Shale	5	520
Lime	20	145	Lime	15	535
Shale	20	165	Shale	45	580
Lime	15	180	Lime	4	584
Shale	25	205	Shale	37	621
Lime	25	230	Sand	15	636
Shale	5	235	Shale	25	661
Lime	25	260	Lime	5	666
Shale	5	265	Shale	20	686
Lime	30	295	Sand	8	694
Shale	5	300	Black shale	28	722
Lime	10	310	Lime, sandy	5	727
Shale	145	455	Gas sand	48	775
Lime	15	470	Shale	5	780

MIAMI COUNTY.

LOG OF WELL OLDHAM No. 27. SEC. 27. T. 16 S., R. 22 E.

Formation	Thickness Feet	Depth Feet	Formation	Thickness Feet	Depth Feet
Clay and sand	18	18	Slate	20	395
Slate	47	65	Sand	192	407
Lime	25	90	Lime	21	428
Slate	27	117	Shale	15	443
Lime	11	188	Lime	4	447
Slate	40	168	Shale	2	449
Lime	7	175	Lime	4	453
Slate	6	181	Shale	10	463
Lime	10	191	Lime	13	476
Shale-gas	2	193	Lime	7	483
Lime	47	240	Lime	8	491
Shale	3	243	Shaley sand	12	503
Lime	16	259	Shale	40	543
Slate	106	365	Sand	13	556
Lime	10	375	Shale	5	561

LOG OF FLAHARTY WELL, SEC. 32, TWP. 18, RANGE 24.

Formation	Thickness Feet	Depth Feet
Oil	2	2
Lime	22	24
Black shale	5	29
Lime	21	45
Black shale	5	50
Lime	4	54
Shale	21	75
Lime	5	80
Blue shale	129	209
Black shale	10	219
White shale	21	240
Lime	12	252
Black shale	11	263
Coal	2	265
Black shale	5	270
Lime	8	278
White shale	6	284
Lime	16	300
Black shale	10	310
Lime, shale	23	333
White shale	3	336
Lime	10	346
Black shale	4	350
Lime	7	357
Black shale	3	360
Sand	10	370
Sandy	80	450
White shale	35	485
Lime	2	487
Black shale	3	490
White shale	15	505
Sand	10	515
Shale	27	542
Sand	2	544
Shale	12	556
Shale	22	566
Sand	2	569
Shale and lime	38	607
Sand	10	617
Shale	5	622
Sand	13	635
Shale	15	650
Sand	5	655
Shale	18	673
*Sand		

**Went 7 feet in and plugged

ALLEN COUNTY.

LOG OF WELL J. M. PRESTON No 9. SEC. 25 T. 24 S., R. 17 E.

Formation	Thickness Feet	Depth Feet
Soil	7	7
Lime	5	12
Shale	118	130
Lime	15	145
Lime	5	155
Lime	5	155
Shale	35	190
Lime	40	235
Shale	25	260
Lime	5	265
Shale	40	305
Lime	65	370
Shale	3	373
Lime	12	385
Sand	5	300
Lime	35	425
Shale	4	429
Lime	6	435
Shale	190	625
Lime	10	635
Shale	20	655
Sand	30	685
Shale	15	700
Lime	40	740
Shale	15	755
Lime	35	790
Shale	5	795
Lime	5	800
Shale	273	1073
Sand	20	1093

Showing of oil in top of sand into water.

LOG OF WELL, F. J. OYLER No. 1, SEC. 1, T. 25 S., R. 17 E.

Formation	Thickness Feet	Depth Feet
Soil	2	2
Clay	18	20
Shale	45	65
Lime	5	70
Shale	35	105
Lime	45	150
Shale	5	155
Sand	30	185
Shale	35	220
Lime	35	255
Sand	5	260
Lime	45	305
Shale	5	310
Lime	50	360
Shale	185	545
Sand	40	585
Shale	3	588
T. D.		588

NEOSHO COUNTY.

LOG OF WELL SKIRVIN No. 1, SEC. 19, T. 27 S., R. 21 E.

Kilpatrick, Stephens & Davis, Sec. 19.27 South—21 East, Neosho County, Kansas.

Formation	Thickness Feet	Depth Feet
Soil	0	15
Shale	15	30
Lime	483	555
Shale	35	60
Lime	60	85
Shale	85	92
Lime	92	96
Lime	111	111
Lime	111	117
Shale	117	150
Lime	150	160
Shale	160	166
Lime	166	196
Shale	196	206
Lime	206	208
Shale	208	240
Hard lime	240	260
Slate	260	267
Hard lime	267	272
Shale	272	390
Lime	390	392
Shale	392	457
Sandy shale	457	462
Shale	462	581
Top of sand	581	
Sand (oil)	581	603

Shot 80 quarts. Fst. 30 bbls.

WILSON COUNTY.

W. K. Mars farm, Section 13, Twp. 28 S., Range 15 W., Wilson County, Kansas.

LOG OF W. K. MARS WELL, SEC. 13, T. 28 S., R. 15 E.

Formation	Thickness Feet	Depth Feet
Lime	0	30
Slate	30	140
Lime	140	175
Slate	175	230
Lime	230	245
Slate	245	270
Sand	270	305
Slate	305	320
Lime and sand	320	335
Lime	335	440
B. sand	440	442
Lime	442	447
Sand	447	452
W. slate	462	465
Lime	465	475
W. slate	475	483
Lime	483	555
B. slate	555	590
W. slate	590	635
Lime and slate	635	665
Slate	665	670
Sand	670	690
W. slate	690	735
Lime	735	770
B. slate	770	780
W. slate	780	800
Lime	800	820
B. slate	820	825
Lime	825	835
Sand	835	895
Slate	895	905
Sand	905	915
B. slate	915	960
W. slate	960	975
Sand	975	980
B. slate	980	990
Lime	990	1000
W. slate	1000	1005
Sand	1005	1010
W. slate	1010	1015
B. slate	1015	1055
S. L. and sand	1055	1110
Sand	1110	1130
B. sand	1130	1175
Slate	1175	1195
Lime	1195	1229
Lime	1226	1244
Rock, red	1244	1254
Lime	1254	1265
Rock, red	1265	1275
Lime	1275	1279
Slate, blue	1279	1336
Lime	1326	1369
Shale, white	1369	1411
Lime	1411	1424
Slate	1424	1438
Lime	1438	1456
Sand and shale	1456	1480
Lime	1480	1540
Slate, blue	1540	1555
Lime	1555	1570
Slate, blue	1570	1572
Lime	1573	1595
Shale, blue	1595	1600
Shells	1600	1635
Lime	1635	1645
Shale	1645	1655
Shale	1655	1660
Shale	1660	1665
Lime	1665	1680
Shale	1680	1685
Lime	1685	1698
Lime	1698	1702
Shale	1702	1719
Lime	1719	1760
Lime	1760	1770
Lime	1770	1784
Slate	1784	1790
Lime	1790	1794
Slate	1794	1808
Slate	1808	1818
Shale	1818	1830
Slate	1830	1865
Slate	1865	1885

LOG OF W. K. MARS WELL—(Continued)

Formation	Thickness Feet	Depth Feet
Slate	1885	1900
Slate, blue	1900	1908
Slate, white	1908	1913
Flint	1913	1920
Slate, blue	1920	1960
Lime, water	1960	2043
Slate	2043	2063
Lime	2063	2089
Blue slate	2089	2100
Lime, brown	2100	2110
Lime, white	2110	2140
Blue slate	2140	2145
Lime	2145	2177
Lime and shale	2177	2192
Lime	2192	2240
Sand	2240	2250
Sandy lime	2250	2274
Sand	2274	2286
Sandy lime	2286	2306
Lime	2306	2311
Sand	2311	2327
Bk. lime	2327	2329
Lime and shale	2329	2334
Sand and lime	2334	2339
Sand and lime	2339	2349
Sand	2349	2354
Sand and slate	2354	2362
Sand	2362	2367
Slate	2367	2617
Rock, red	2617	2622
Slate	2622	2627
Sand	2627	2732*

*Total depth.

MONTGOMERY COUNTY.
LOG OF WELL W. T. OLIVER No. 9, SEC. 35, T. 31 S., R. 13 E.

Formation	Thickness Feet	Depth Feet
Soil	5	5
Clay	15	20
Sand	10	30
Gravel	5	35
Shale	80	115
Lime	10	125
Shale	10	135
Lime	55	190
Shale	248	438
Lime	122	560
Shale	75	635
Lime	40	675
Dark shale	78	753
Lime	2	755
Sand	10	765
Shale	85	850

LOG OF WELL ALBERT FECHT No. 4, SEC. 3, T. 35 S., R. 14 E.

Formation	Thickness Feet	Depth Feet
Dirt, sand	8	8
Sand rock, shells	10	18
Sand, water	8	26
White mud	100	126
White shale	80	206
Lime rock	10	216
White shale	40	256
Lime	10	266
Brown shale	45	311
Lime	12	323
Sand, water	15	338
Brown shale	40	378
Sand, water	20	398
White shale	100	498
Lime	13	511
White shale	60	571
Sand, water	10	581
White shale	20	601
Limy shale rock	175	776
BIG LIME with shells and water	100	876
White shale	150	1026
OSWEGO LIME, some break	120	1146
Brown shale	50	1196
Lime	10	1206
Brown shale	75	1281
Lime	6	1287
White shale	6	1293
Sandy shale	50	1343
Lime, shelly	11	1354
Bartlesville sand	9	1363
Black shale	9	1372*

*Total depth.

CHAUTAUQUA COUNTY.
LOG OF WELL E. E. SHAFFER No. 1, SEC. 12, T. 32 S., R. 9 E.

Formation	Thickness Feet	Depth Feet
Soil	15	
Clay	6	25
Lime	10	35
Yellow clay	5	40
Lime	5	45
Sandy shale	5	50
Lime	9	54
Red rock	6	60
Lime	92	162
Shale	8	170
Lime	5	175
Shale	10	185

LOG OF E. E. SHAFFER WELL—(Continued.)

Formation	Thickness Feet	Depth Feet	Formation	Thickness Feet	Depth Feet
Lime	25	210	Set 10 inch casing	7	663
Shale	6	216	Lime	2	665
Lime	24	230	Shale	15	680
Shale	8	238	Lime	16	696
Lime-shell	10	248	Shale	14	710
Black shale	12	260	Lime	10	720
Red rock	5	265	Shale	5	725
Sand	15	280	Lime	5	730
White shale	10	290	Shale	60	795
Red rock	20	310	Lime	30	825
Lime	2	312	Shale	5	830
Blue shale	8	320	Lime	30	860
12½ inch casing set in black shale			Hard sand	5	865
Blue shale	30	350	Brown shale	25	890
Sand	15	360	Hard lime	75	1065
Blue shale	15	365	Brown sand—water	15	1080
White shale	35	390	Black shale	20	1100
Sand—two bailers water	26	416	Brown shale	10	1110
Shale	14	430	Lime shell	30	1140
Sand—ten bailers water	5	435	Shale	10	1150
Shale	15	450	Lime	12	1162
Black shale	65	515	Shale	8	1170
Lime	6	521	Black lime	90	1260
Shale	15	536	Shale	20	1280
Sand—hole full water	24	560	Black	55	1335
Red rock	6	566	Lime	5	1340
Shale	14	570	Sand—seven bailers water	7	1347
Lime	38	608	Lime	11	1358
Red rock	12	620	Gas	29	1387
Lime	10	630	Shale	11	1398
Shale	26	656	Total depth		1400

LOG OF WELL ZIMMERMAN No. 1, SEC. 3, T. 33 S., R. 11 E.

Formation	Thickness Feet	Depth Feet	Formation	Thickness Feet	Depth Feet
B. lime	5		Black shale	1010	1015
Clay	5	15	Black shale	1015	1040
Lime and shale	15	17	Stray sand	1040	1070
Shale	3	20	Shale	1070	1130
Lime	20	23	Black shale	1130	1145
Shale	23	30	Lime	1145	1150
Lime	30	35	Shale	1150	1160
Shale	35	45	Peru broken sand	1160	1175
Lime	45	50	Shale	1175	1230
Shale	50	60	Lime	1230	1270
Lime	60	65	Sand, broken	1270	1330
Red rock	65	75	Shale	1330	1345
Gray sand	75	85	Lime	1345	1375
Red rock	85	95	Black shale	1375	1395
Quick sand	95	110	Lime	1395	1430
Shale	110	155	Black shale	1430	1435
H-20 sand	155	165	Lime	1435	1443
Shale	165	230	Black shale	1443	1453
Sand	285	275	Black sand	1453	1458
Bad mud	275	305	Shale	1458	1468
White shale	305	315	Lime	1468	1472
Lime	315	318	Shale	1472	1500
Dark shale	318	400	Lime	1500	1510
Sand	400	408	Shale	1510	1590
Shale and breaks	408	423	Sand	1590	1605
Shale	423	590	Shale	1605	1650
Lime	590	605	Lime	1650	1653
Sand lime	605	710	Shale	1653	1670
Shale	710	806	Red shale	1670	1710
Black shale	806	840	White shale	1710	1730
Salt sand	840	850	Slate, black	1730	1737
Shale	950	1010	M'cs. lime.		

LOG OF WELL ALBRIGHT No. 1, SEC. 18, T. 35 S., R. 11 E.

Formation	Thickness Feet	Depth Feet
Rock, sandstone	20	20
Shale	75	95
Shell	5	100
Shale	40	140
Sand	25	165
Shale	75	240
Lime	5	245
Shale	5	250
Lime	5	255
Shale, sandy	165	420
Shale	45	465
Lime	10	475
Sand	75	550
Sandy shale	5	555
Sand	35	590
Sandy shale	20	610
Black shale	105	715
Sand, big salt sand	85	800
Sandy shale, break	15	815
Sand, big salt sand	60	875
Shale	35	910
Shale, black	45	955
Stray sand	58	1013
Shale	97	1110
Cap rock	12	1122
Shale	58	1184
Lime, big lime	50	1230
Shale	81	1311
Lime, Ft. Scott or Oswego	25	1336
Break black slate	15	1351
Lime	21	1372
Break	10	1382
Lime	35	1427
Black shale and shells	85	1512
Black slate	7	1519
Lime cap	3	1522
Sand	20	1542
Sandy shale	25	1567
Blue shale	15	1582
Black	5	1587
Sand, Bartlesville	15	1602
Sandy shale	40	1642
Black shale	28	1670
Sandy shale	15	1685
Shale	71	1756
Mississippi lime	83	1739

BUTLER COUNTY.
AUGUSTA POOL.
LOG OF WELL LAYTON No. 1, SEC. 35, T. 27 S., R. 4 E.

Formation	Thickness Feet	Depth Feet
Slate, shale, hard	2	2
Lime, gray, hard	98	100
Shale, dark, hard	25	125
Red rock, soft	5	130
Shale, dark, soft	10	140
Lime, gray, soft	15	155
Sand, white, soft	15	170
Lime, gray, hard	3	175
Shale, red, soft	10	185
Lime, gray, hard	50	235
Slate, white, soft	40	275
Lime, gray, hard	50	325
Sand, gray, soft	10	335
Lime, gray, hard	80	415
Slate, light, hard	30	445
Sand, light, hard	10	455
Lime, gray, hard	15	470
Slate, dark, soft	10	480
Lime, dark, hard	20	500
Slate, dark, hard	50	550
Lime, white	25	575
Red rock	10	585
Slate, red	45	630
Slate, brown, soft	25	655
Sand, brown, soft	20	675
Slate, brown, soft	11	686
Slate, brown, soft	54	740
Lime, brown, hard	5	745
Slate, brown, soft	25	770
Lime, white, hard	5	775
Slate, brown, soft	15	790
Lime, brown, hard	20	810
Slate, dark, soft	20	830
Lime, gray, hard	4	834
Slate, black, soft	21	8 5
Lime, gray, hard	15	870
Slate, black, soft	10	880
Lime, gray, hard	10	890
Lime, black, soft	22	912
Slate, gray, hard	6	918
Lime, black, soft	6	924
Lime, hard	6	930
Slate, blue, soft	15	945
Shells, slate, hard	20	965
Slate, white, hard	10	975
Lime, white, hard	5	980
Slate, black, soft	10	990
Slate, white, hard	25	1015
Lime, white, hard	20	1035
Slate, blue, hard	20	1055
Lime, white, hard	10	1065
Slate, blue, soft	10	1075
Lime, white, soft	10	1085
Lime, gray, hard	15	1100
Slate, dark, soft	20	1120
Slate, white, soft	5	1125
Lime, gray, hard	20	1145
Slate, black, soft	5	1150
Lime, blue, hard	5	1155
Lime, white, hard	6	1161
Lime, white, hard	12	1173
Slate, blue, soft	25	1198
Lime, blue, hard	2	1200
Sand, black, hard	8	1208
Lime, blue, hard	10	1218
Lime, white, hard	18	1236
Lime, white, hard	4	1240
Slate, black, soft	5	1245
Lime, black, soft	20	1265
Slate, black, ard	2	1267
Slate, white, hard	13	1280
Lime, white, hard	22	1302

LOG OF LAYTON WELL No. 1—(Continued.)

Formation	Thickness Feet	Depth Feet	Formation	Thickness Feet	Depth Feet
Slate, black, soft	3	1305	Sand, white, hard	10	2150
Lime, white, hard	10	1315	Lime, white, h rd	10	2160
Lime, white, hard	40	1355	Slate, blue	15	2175
Lime, white, hard	18	1373	Lime, white, soft	10	2185
Lime, white, hard	7	1380	Lime, white, hard	10	2195
Lime, black, soft	7	1387	Sand, hard	6	2201
Slate, black, soft	20	1407	Lime, brown	17	2218
Lime, white, hard	12	1419	Lime, white, hard	2	2220
Lime, white, hard	11	1430	Slate, blue, hard	10	2230
Lime, brown, hard	5	1435	Lime, white, soft	7	2237
Lime, brown, hard	15	1450	Slate & shells, soft	5	2242
Lime, white, hard	30	1480	Slate, blue, soft	10	2252
Slate, black, soft	3	1483	Lime, shells, hard	5	2257
Lime, white, hard	3	1486	Slate, black, soft	11	2268
Slate, white, hard	21	1507	Slate, blue, hard	12	2280
Slate and shells, white, soft	13	1520	Sand, white, soft	38	2318
Sand, soft	30	1550	Sand, blue, soft	10	2328
Sand, black, soft	60	1610	Lime, white, soft	30	2358
Sand, black, hard	10	1620	Lime, white, hard	2	2360
Slate, shells, hard	3	1623	Lime, slate, hard	8	2368
Slate, shells, hard	22	1645	Lime, white, soft	5	2373
Slate, black, soft	5	1650	Lime, blue, soft	12	2385
Lime, white, hard	25	1675	Slate, blue, hard	10	2395
Slate, white, soft	3	1678	Slate, dark, soft	10	2405
Lime, blue, hard	10	1688	Lime, brown, hard	5	2410
Lime, blue, hard	5	1693	Slate, blue, soft	25	2435
Slate, black, soft	18	1711	Slate, dark, soft	28	2463
Lime, blue, hard	3	1714	Lime, brown, hard	7	2470
Lime, white, hard	18	1732	Slate, blue, soft	6	2476
Lime, white, hard	12	1744	Slate, white, soft	4	2480
Slate, brown, soft	16	1760	Slate, white, soft	12	2492
Lime, white, hard	22	1782	Slate, black, soft	6	2498
Lime, white, hard	10	1792	Lime, black, hard	2	2500
Lime, white, hard	27	1819	Lime, black, hard	16	2516
Lime, white, hard	18	1837	Slate, white, soft	9	2525
Lime, white hard	17	1854	Slate, white, soft	3	2528
Lime, white, hard	8	1862	Sand, black, hard	2	2530
Lime, brown	23	1985	Rock, red, soft	9	2539
Lime, blue, soft	15	2000	Lime, brown, hard	8	2547
Slate, lime, soft	4	2004	Slate, blue, soft	10	2557
Slate, white, soft	21	2025	Slate, black, hard	8	2565
Lime, white, hard	25	2050	Sand, white, hard	29	2594
Slate, lime, soft	20	2070	Slate, black, hard	45	2639
Slate, gray, hard	5	2075	Sand, black, hard	3	2642
Lime, gray, hard	3	2078	Sand, light, hard	6	2648
Sand, gray, soft	7	2085	Sand, green, hard	16	2664
Lime, gray, hard	19	2104	Sand, gray, hard	6	2670
Lime and slate, hard	16	2120	Sand, blue, hard	5	2675
Lime, blue, hard	20	2140	2675 total depth of well.		

LOG OF WELL, BRANT No. 3, SEC. 2, T. 28 S., R. 4 E.

Formation	Thickness Feet	Depth Feet	Formation	Thickness Feet	Depth Feet
Soft soil	3	3	Shale	150	1025
Lime	47	50	Shale	125	1150
Lime	47	97	Lime	80	1230
Slate	18	115	Lime	20	1250
Slate sand shell	55	170	Lime	65	1315
Slate and shell	95	265	Lime and shell	55	1370
Shale and slate	120	385	Shale	70	1440
Lime	95	480	Shale	15	1540
Lime	30	510	Shale	100	1640
Shell and slate	105	615	Shale	60	1700
Slate and shell	135	750	Lime	15	1715
Shell and slate	125	875	Lime	60	1775

LOG OF BRANT WELL No. 3—(Continued.)

Formation	Thickness Feet	Depth Feet	Formation	Thickness Feet	Depth Feet
Lime	35	1810	Slate	23	2300
Lime	60	1870	Shale	15	2315
Lime	30	1900	Shell and slate	65	2380
Lime	25	1925	Slate and sand	120	2500
Shale	55	1980	Slate	50	2550
Sand slate and shell	100	2080	Sand	20	2570
Lime	40	2120	Sand and lime	30	2600
Lime	30	2150	Sand and lime	5	2605
Lime	30	2180	Sand	5	2610
Lime	20	2200	Sand	5	2615
Lime	25	2225	Sand	5	2620
Lime	25	2250	Sand	5	2625*
Slate	30	2280	*Total depth 2625		

LOG OF WELL SCULLY No. 8, SEC. 21, T. 27 S., R. 4 E.

Formation	Thickness Feet	Depth Feet	Formation	Thickness Feet	Depth Feet
S. black soil	20	20	S. blue slate	65	1320
S. gray gravel	5	25	H. white lime	80	1400
H. white lime	45	70	S. blue slate	40	1440
S. black slate	40	110	H. white lime	15	1455
S. & H. white slate shells	45	155	S. blue slate	95	1550
H. white sandy lime	25	180	H. white lime	245	1795
S. blue slate	40	220	S. blue slate	115	1910
H. white lime	40	260	S. gray sandy lime	155	2065
S. white slate	70	330	S. blue slate	5	2070
H. white lime	30	360	H. white lime	30	2100
S. white slate	100	460	S. blue slate	10	2110
S. black slate	142	602	H. white lime	20	2130
S. & H. white lime shells	10	612	S. blue slate	15	2145
S. white slate	73	685	H. white lime	15	2160
H. white lime	90	775	S. white shale	60	2220
S. white slate	105	880	S. blue slate	80	2300
H. white lime	60	940	H. white lime	7	2307
S. white slate	70	1010	S. gray oil sand	92	2399*
H. white lime	245	1255	*Total depth 2399		

ELDORADO POOL.

LOG OF WELL PARSLEY No. 1, SEC. 23, T. 25 S., R. 4 E.

Formation	Thickness Feet	Depth Feet	Formation	Thickness Feet	Depth Feet
Soil, light, soft	30	30	Sand, gray, medium	5	700
Lime, light, hard	25	55	Slate, black soft	5	705
Shale, red, soft	25	80	Slate, blue soft	41	746
Sand, white, hard	20	100	Rock, red, soft	15	761
Shale, blue, soft	12	112	Shale, blue, soft	47	808
Sand, gray, hard	8	120	Sand, gray, soft	20	828
Lime, shale	100	220	Shale, blue, soft	152	980
Shale, blue, soft	15	235	Lime, light, hard	40	1020
Lime, shell, gray	25	260	Shale, blue, soft	122	1142
Red rock, soft	5	265	Lime, light hard	25	1167
Lime, shell, gray	30	295	Shale, blue, soft	33	1210
Red rock, soft	15	310	Sand, lime, light	10	1220
Lime, gray, medium	35	345	Shale blue, soft	46	1266
Shale, blue, soft	133	478	Lime, white, hard	20	1286
Sand, dark, soft	20	498	Shale, blue, soft	6	1291
Shale, blue, soft	100	598	Lime, blue, hard	20	1311
Lime, dark, hard	15	613	Shale, blue, soft	10	1321
Shale, blue, soft	10	623	Lime, gray, hard	10	1331
Lime, dark, hard	8	631	Shale, blue, soft	3	1334
Shale, blue, soft	58	689	Lime, light, hard	45	1379
Sand, gray, hard	2	691	Shale, blue, soft	10	1389
Slate, black, soft	4	695	Shale, gray, hard	12	1401

LOG OF PARSLEY WELL No. 1—(Continued.)

Formation	Thickness Feet	Depth Feet
Blue shale, soft	14	1415
Lime, light, hard	40	1455
Shale, blue, soft	5	1460
Lime, light, hard	3	1463
Shale, gray, soft	10	1473
Lime, light, hard	37	1510
Lime, light, hard	10	1525
Shale, blue, soft	45	1570
Lime, light, hard	20	1590
Shale, black, soft	8	1598
Shale, blue, soft	27	1625
Lime, ligh', hard	14	1639
Shale, blue, soft	23	1662
Lime, light, hard	5	1667
Shale, blue, soft	33	1700
Sand, gray, soft	20	1720
Shale, blue, soft	38	1758
Sand, light, soft	7	1765
Shale, blue, soft	33	1798
Sand, light, hard	5	1803
Shale, blue soft	17	1820
Lime, white, hard	20	1840
Shale, blue, soft	55	1895
Sand, gray, medium	5	1900
Lime, light, hard	151	2051
Shale, blue, soft	120	2171
Shale, black, soft	12	2185
Lime, white, hard	13	2200
Sand, gray, soft	6	2206
Lime, light, hard	110	2316
Shale, black, soft	6	2322
Sand, gray, hard	7	2329
Lime, light, hard	5	2334
Shale, blue, soft	6	2340
Lime, light, hard	6	2346
Shale, blue soft	60	2406
Lime, light, hard	2	2408
Slate, light, medium	8	2416
Lime, light, hard	2	2418
Shale, blue, soft	5	2423
Lime, light, hard	2	2425
Shale, blue, soft	2	2427
Sand, gray, soft	2	2429
Sand, gray, soft	3	2432
Sand, gray, hard	5	2457
Sand, gray, hard	5	24[illegible]7
Shale, dark, hard	20	2477
Lime, gray, hard	7	2484
Shale, blue, soft	50	2534
Lime, gray, hard	10	2544
Shale, blue, soft	80	2624
Lime, gray, hard	5	2629
Shale, blue, soft	50	2679
Lime, gray, hard	8	2687
Shale, dark, soft	10	2697
Shale, red, soft	6	2703
Lime, gray, hard	16	2719
Sand, white, hard	18	2727
Lime, white, broken	80	2817
Shale, blue, soft	10	2827
Lime, gray, hard	30	2857
Shale, blue, soft	40	2897
Lime, white, hard	20	2917
Shale, blue, soft	30	2947
Lime, white, hard	10	2957
Shale, blue, soft	31	2988
Sand, gray, soft	13	3001

LOG OF WELL FOWLER No. 1, SEC. 1, T. 26 S., R. 4 E.

Formation	Thickness Feet	Depth Feet
Soil	5	5
Lime	95	100
Slate	25	125
Lime	25	150
Slate	20	170
Lime	10	180
Slate	16	196
Slate	130	326
Red rock	10	336
Slate	24	360
Slate	105	465
Slate	110	575
Slate	10	585
Lime	10	595
Slate	5	600
Slate	45	645
Lime	55	700
Slate	65	765
Lime	35	800
Lime	10	810
Slate	15	825
Lime	45	870
Slate	5	875
Lime	25	900
Slate	25	925
Lime	25	850
Slate	9	959
Lime	50	1009
Slate	15	1024
Lime	26	1050
Slate	40	1090
Lime	15	1105
Slate	10	1115
Lime	30	1145
Slate	25	1170
Lime	10	1180
Slate	5	1185
Lime	25	1210
Slate	10	1220
Lime	15	1235
Slate	20	1255
Lime	25	1280
Slate	20	1300
Lime	60	1360
Slate	5	1365
Lime	15	1380
Slate	10	1390
Slate	10	1400
Slate	5	1405
Lime	10	1415
Lime	20	1435
Slate	25	1460
Lime	10	1470
Lime	20	1490

LOG OF FOWLER WELL No. 1—(Continued.)

Formation	Thickness Feet	Depth Feet	Formation	Thickness Feet	Depth Feet
Slate	10	1500	Sand	5	2045
Lime	20	1520	Lime	20	2065
Slate	30	1550	Lime	20	2085
Slate	55	1605	Lime	10	2095
Lime	7	1612	Lime	5	2100
Slate	13	1625	Lime	45	2145
Slate	2	1627	Lime	25	2170
Lime	2	1629	Slate	25	2195
Slate	10	1639	Slate	40	2235
Slate	15	1654	Slate	40	2275
Lime	5	1659	Slate	30	2305
Lime	65	1724	Slate	30	2335
Slate	20	1744	Lime	10	2345
Lime	30	1774	Slate	20	2365
Lime	21	1795	Sand	25	2390
Lime	45	1840	Slate	45	2435
Shale	50	1890	Sand	35	2470
Shale	60	1950	Slate	35	2505
Shale	25	1975	Sand (oil)	8	2513*
Shale	25	2000	Sand (oil)	9	2522
Lime	5	2005	Sand, (oil)	4	2526
Lime	35	2040	* A good showing.		

LOG OF KENNEDY WELL, SEC. 34, T. 26 S., R. 5 E

Formation	Thickness Feet	Depth Feet	Formation	Thickness Feet	Depth Feet
Soil	0	4	Slate	1120	1175
Lime	4	108	Lime	1175	1215
Dark shale	108	140	Slate	1215	1220
Red rock	140	148	Lime	1220	1260
Lime	148	185	Slate	1260	1300
Red rock	185	190	Lime	1300	1360
Shale	190	220	Sand	1360	1380
Lime	220	230	Lime	1380	1445
Shale white	230	245	Shale	1445	1470
Lime	245	300	Lime	1470	1560
Black slate	300	325	Shale	1560	1600
Sand	325	345	Lime	1600	1607
Lime	345	390	Shale	1607	1650
Shale	390	405	Lime	1650	1660
Lime	405	455	Slate	1660	1740
Shale	455	470	Lime	1740	1760
Lime	470	520	Slate	1760	1865
Shale	520	600	Lime	1865	1925
Red rock	600	605	Slate	1925	1980
Slate	605	700	Sand	1980	1995
Lime	700	720	Lime	1995	2010
Shale	720	745	Slate	2010	2175
Sand	745	770	Lime	2175	2240
Lime	770	780	Sand	2240	2285
Slate	780	805	Slate	2285	2320
Shale	805	825	Sand, white	2320	2330
Lime	825	865	Lime	2330	2348
Slate	865	880	Slate, black	2348	2375
Lime	880	915	Lime, white	2375	2380
Slate	915	975	Slate, white	2380	2418
Lime	975	990	Sand	2418	2455
Slate	990	1050	Lime, gray	2455	2470
Lime	1050	1065	Slate, black	2470	2480
Slate	1065	1075	Lime, white	2480	2485
Lime	1075	1120	Slate, black	2485	2530

OKLAHOMA.

NOWATA DISTRICT.

Coody's Bluff-Alluwe Pool—For the Alluwe portion of the Pool.

LOG OF WELL MAJORA E. CAREY No. 4, IN SEC. 19, T. 25 N., R. 17 E.

Formation	Thickness Feet	Depth Feet	Formation	Thickness Feet	Depth Feet
Soil	15	15	Sand	12	132
Gravel	5	20	Shale	246	378
Shale	15	35	Sand	11	389
Lime	30	65	Shale	20	409
Shale	5	70	Sand	6	415
Lime	8	78	Shale	37	452
Shale	20	98	Oil sand	12	464
Lime	5	103	Shale	5	469
Shale	17	120			

For the Coody's Bluff portion of the pool.

LOG OF WELL No. 2, IN SEC. 13, T. 26 N., R. 16 E.

Formation	Thickness Feet	Depth Feet	Formation	Thickness Feet	Depth Feet
Soil	15	15	Lime	8	198
Gravel and sand	21	36	Light shale	30	228
Light shale	84	120	Lime	10	238
Lime	18	138	Light shale	262	500
Dark shale	8	146	Oil sand	31	531
Lime	40	186	Dark shale	15	546
Dark shale	4	190			

LOG OF WELL HILL, N. E. OF ALLISON PUMP HOUSE, SEC. 24, T. 26 N., R. 16 E.

Formation	Thickness Feet	Depth Feet	Formation	Thickness Feet	Depth Feet
Lime	35	35	Shale	30	318
Shale	175	210	Lime	10	328
Lime	20	230	Shale	242	570
Shale	8	238	Gas sand	20	590
Lime	50	288	Oil sand	20	610

Nowata or Claggett Pool.

LOG OF WELL CHAS. CLAGGETT No. 1, IN SEC. 17, T. 26 N., R. 16 E.

Formation	Thickness Feet	Depth Feet	Formation	Thickness Feet	Depth Feet
Shale	40	40	Black shale	10	390
Lime	30	70	Lime	12	402
Black slate	15	85	Black shale	25	427
White slate	10	95	Lime	8	435
Lime, Pawnee	40	135	Black shale	30	465
Black shale	5	140	White shale	35	500
White shale	10	150	Sand	25	525
Sand	35	185	Black shale	30	555
Black shale	115	300	Shale, banded	161	716
Lime	30	330	Oil sand	20	736
Black shale	10	340	Slate	5	741
Lime	40	380	Sand	12	753
			Shale	5	758

LOG OF WELL MARY METRER No. 1, SEC. 19, T. 26 N., R. 11 E.

Formation	Thickness Feet	Depth Feet	Formation	Thickness Feet	Depth Feet
Surface and shale	85	85	Limestone	10	450
Limestone	25	110	Shale	30	480
Shale	25	135	Limestone	6	486
Limestone	40	175	Shale	19	505
Shale	200	375	Sand	35	540
Limestone	20	395	Shale	95	635
Shale	5	400	Sand	20	655
Limestone	35	435	Shale	96	751
Shale	5	440	Oil sand	21	772

Delaware-Childers Pool.

LOG OF WELL HENRY ROBBINS No. 1, IN N. E. ¼ S. E. ¼ SEC. 28, T. 27 N., R. 16 E.

Formation	Thickness Feet	Depth Feet	Formation	Thickness Feet	Depth Feet
Lime	25	25	Shale	12	368
Shale	55	80	Lime	12	380
Lime	50	130	Shale	30	410
Shale and sand	150	280	Lime	8	418
Lime	30	310	Shale	252	670
Shale	6	316	Gas sand	10	680
Lime	40	356	Oil sand	40	720

California Creek Pool.

LOG OF WELL DANIEL LOWERY, SEC. 26, T. 28 N., R. 15 E.

Formation	Thickness Feet	Depth Feet	Formation	Thickness Feet	Depth Feet
Soil	4	4	Shale	6	526
Clay	11	15	Lime	35	561
Shale	20	35	Shale	5	566
Sand	5	40	Lime	8	574
Light shale	40	80	Shale	25	599
Dark shale	100	180	Lime	8	607
Brown shale	50	230	Shale	100	707
Shale	70	300	Lime	5	712
Limestone	65	365	Light shale	40	752
Shale	20	385	Dark shale	100	852
Sand	30	415	Light shale	200	1052
Sand	5	420	Dark shale	59	1111
Shale	65	485	Miss. lime	9	1120
Lime	35	520			

BARTLESVILLE DISTRICT.

Canary Pool.

LOG OF WELL EMMA WELCH No. 2, SEC. 18, T. 29 N., R. 14 E.

Formation	Thickness Feet	Depth Feet	Formation	Thickness Feet	Depth Feet
Big lime	65	670	Gas sand	20	1241
Oswego lime	90	870	Oil sand	41	1309

Capan Pool.

LOG OF WELL JANE HILL No. 2, SEC. 35, T. 29 N., R. 13 E.

Formation	Thickness Feet	Depth Feet	Formation	Thickness Feet	Depth Feet
Little lime (Lenapah)	20	565			
Big lime	90	780	Gas sand	20	1265
Oswego lime	80	990	Oil sand	33	1309

LOG OF WELL WILLIAM MILLER No. 6, NE. ¼, SEC. 1, T. 28 N., R. 13 E.

Formation	Thickness Feet	Depth Feet	Formation	Thickness Feet	Depth Feet
Soil and clay	20	20	Sand and shale	50	420
Limestone	5	25	Big lime	315	735
Sand, soft	40	65	Shale	65	800
Shale	95	160	Limestone	35	835
Sand, soft	40	200	Limestone	5	840
Shale	50	250	Shale	110	950
Limestone	20	270	Oswego lime	80	1030
Shale	100	370	First show of oil		1331

Dewey-Bartlesville Pool

LOG OF WELL ALBERT WHITETURKEY No. 1, SEC. 18, T. 26 N., R. 13 E.

Formation	Thickness Feet	Depth Feet	Formation	Thickness Feet	Depth Feet
Shale	84	84	Black Slate	21	893
Lime (Dewey)	30	114	Oil sand	19	913
Sand and shale with limestone	346	460	Sand and shale	245	1158
Lime (Lenapah)	30	490	Gas sand	7	1165
Sand and shale	104	594	Shale	30	1195
Big lime	70	664	Gas sand	85	1280
Sand and shale	136	800	Oil sand	30	1310
Oswego lime	73	873			

LOG OF WELL MINNIE OSAGE No. 1, SEC. 9, T. 26 N., R. 13 E.

Formation	Thickness Feet	Depth Feet	Formation	Thickness Feet	Depth Feet
Clay	30	30	Oswego lime	90	965
Lime (Dewey)	30	60	Slate	50	1015
Slate	180	240	Sand	25	1040
Sand	25	265	Slate	252	1292
Slate	235	500	Bartlesville sand	3	1295
Lime (Lenapah)	40	540	Slate	80	1375
Slate	130	670	Lime	5	1380
Big lime	60	730	Slate	92	1472
Slate	95	825	Sand	3	1475
Sand	35	860	Mississippi lime		1475
Slate	15	875			

Squirrel Pool.

LOG OF WELL LIZZIE SUNDAY No. 4, SEC. 7, T. 26 N., R. 14 E.

Formation	Thickness Feet	Depth Feet	Formation	Thickness Feet	Depth Feet
Soil	5	5	Shale	120	870
Limestone	15	20	Oswego limestone	35	905
Shale	40	60	Shale	5	910
Limestone	55	115	Hard limestone	10	920
Shale	125	240	Shale	140	1060
Limestone	10	250	Limestone	40	1100
Black shale	200	450	Shale	142	1242
Limestone	100	550	Oil sand	27	1269
Shale	130	680	Oil at 1230.		
Big limestone	70	750			

LOG OF WELL NANCY WATTIE, SEC. 7, T. 26 N., R. 14 E.

Formation	Thickness Feet	Depth Feet	Formation	Thickness Feet	Depth Feet
Soil	5	5	Shale	200	415
Limestone	10	15	Limestone	25	440
Shale	80	95	Shale	199	639
Limestone	50	145	Shale	6	645
Shale	30	175	Shale	72	717
Limestone	40	215	Sand	30	747

Hogshooter Pool.

LOG OF WELL JOHN LOWERY, JR., No. 2, SEC. 6, T. 25 N., R. 14 E.

Formation	Thickness Feet	Depth Feet	Formation	Thickness Feet	Depth Feet
Shale	12	460	Lime	35	495
Clay	40	40	Shale	135	648
Gravel	4	44	Lime	26	674
Shale	46	90	Shale	5	679
Sand	10	100	Lime	32	711
Shale	108	-08	Shale	4	715
Sand	12	220	Lime	8	723
Shale	80	300	Sand	40	763
Lime	8	308	Shale	278	1041
Shale	112	420	Oil sand	21	1062
Lime	23	448	Shale	17	1079

TULSA DISTRICT.

Bird Creek—Flat Rock Pool

LOG OF WELL VIOLA B. THOMAS No. 1, SEC. 7, T. 20 N., R. 13 E.

Formation	Thickness Feet	Depth Feet	Formation	Thickness Feet	Depth Feet
Soil	20	20	Sand and shells	90	990
Slate, white	25	45	Shells	5	995
Shells	5	50	Slate, black	50	1045
Slate, white	50	100	Lime	10	1055
Slate, blue	60	160	Slate, black	30	1085
Coal	6	166	Shells	5	1090
Mud	31	200	Shale	35	1125
Slate	50	250	Lime	25	1150
Slate, brown	45	295	Slate, black	40	1190
Shells	5	300	Sand, water	70	1260
Lime, white	25	325	Lime	40	1300
Lime	110	435	Sand, water	30	1330
Sand	15	450	Slate	15	1345
Shale	10	460	Slate, black	20	1365
Sand and shells	15	475	Lime, gray	10	1375
Shale	75	650	Sand (Burgess)	10	1385
Lime	35	685	Sand, water	10	1395
Shale	80	765	Sand, black, water	10	1405
Lime, gas	10	775	Slate	110	1515
Sand and shells	50	825	Sand and lime	5	1520
Sand, water	75	900			

LOG OF WELL, SEC. 28, T. 21 N., R. 1› E

Formation	Thickness Feet	Depth Feet	Formation	Thickness Feet	Depth Feet
Soil	14	14	Lime	15	685
Lime, gritty	25	39	Shale	211	896
Shale	231	270	Lime	10	906
Lime (big)	130	400	Shale	152	1058
Shale	167	567	Sand, gas	78	1136
Lime (Oswego)	48	615	Sand, oil	23	1159
Shale	53	[illegible]			

Owasso Gas Pool.

LOG OF WELL ANDREAS LEERSKOW No. 3, N. ½ NE. ¼, SEC. 30, T. 21 N., R. 14 E.

Formation	Thickness Feet	Depth Feet	Formation	Thickness Feet	Depth Feet
Soil	14	14	Lime (?)	30	530
Slate	21	35	Slate	80	610
Lime (Big)	100	135	Lime	10	620
Slate	225	360	Shale	242	862
Lime (Oswego)	30	390	Sand and gas	14	876
Slate	110	500	Slate, black	15	891

SAPULPA DISTRICT.

Glenn Pool.

LOG OF WELL LIZZIE COSER No. 13, SEC. 13, T. 17 N., R. 12 E.

Formation	Thickness Feet	Depth Feet	Formation	Thickness Feet	Depth Feet
Soil	12	12	Shells	30	875
Slate	88	100	Shale	96	971
Sand	30	130	Sand	44	1015
Slate	40	170	Shale	215	1230
Sand	30	200	Sand (Red Fork)	25	1255
Slate	390	590	Brown shale	92	1347
Lime	25	615	White shale	28	1375
Slate	55	670	Stray sand	55	1430
Lime	35	705	Gas sand (Glenn)	30	1460
Shale	115	820	Oil sand (Glenn)	32	1492
Lime (Oswego?)	25	845			

Taneha Pool

LOG OF WELL ALVIN G. LAND, SEC. 1, T. 18 N., R. 11 E.

Formation	Thickness Feet	Depth Feet	Formation	Thickness Feet	Depth Feet
Soil	10	10	Shale	25	1000
Shale	230	240	Lime	10	1010
Lime	5	245	Shale	65	1075
Shale	15	260	Sand	20	1095
Sand	40	300	Shale	75	1170
Shale	90	390	Sand	30	1200
Sand	10	400	Shale	125	1325
Shale	300	700	Sand	25	1350
Lime	50	750	Sand and shells	40	1390
Shale	110	860	Shale	70	1460
Lime	40	900	Sand (oil)	10	1470
Lime shells	25	925	Shale	190	1660
Sand	50	975	Sand	4	1704

1,000,000 cubic feet of gas at 1360.

OKMULGEE DISTRICT.

Morris Pool.

WELL IN MORRIS FIELD, SW. ¼ SEC. 5, T. 13 N., R. 14 E.

Formation	Thickness Feet	Depth Feet	Formation	Thickness Feet	Depth Feet
Conductor	18	18	Shale	85	782
Shale	4	22	Lime	80	862
Coal	3	25	Sand	100	962
Shale	100	125	Lime	29	991
Sand	12	137	Shale	257	1248
Shale	45	182	Sand	20	1268
Sand and shale	30	212	Shale	307	1575
Shale	215	427	Oil sand (show of oil)	20	1595
Lime	10	437	Shale	110	1705
Shale	250	687	Sand and lime with show of oil	72	1778
Sand	10	697			

Gas appeared at 1757 feet and increased to bottom of hole. Later the well was sunk to a depth of 1800 feet and the sand was still present.

Preston Pool.

LOG OF WELL ALEX. PRESTON No. 1, SEC. 11, T. 14 N R. 12 E.

Formation	Thickness Feet	Depth Feet
Soil	15	15
Shelly	110	125
White slate	190	315
Black slate	38	353
White slate	172	525
Black slate	10	535
White slate	115	650
Lime	12	662
White slate	8	670
Lime	20	690
Black slate	65	755
White slate	85	840
Brown sand	75	915
White slate	10	925
Black slate	35	960
White slate	10	970
Brown sand	540	1020
White slate	170	1190
Black slate	20	1215
White slate	105	1320
Black slate	65	1385
Sand (oil and gas)	165	1550
Black slate	30	1580
White slate	120	1700
Black slate	48	1743
Oil sand	9	1752
Slate	268	2020
Gas sand	15	2035
Oil sand	3	2038

Tiger Flats Pool.

LOG OF WELL PERRYMAN No. 2, SEC. 22, T. 13 N., R. 11 E.

Formation	Thickness Feet	Depth Feet
Soil	15	15
Sand	140	155
Slate	20	175
Sand	75	250
Slate	75	325
Sand	105	430
Slate	350	780
Sand	15	795
Slate	100	895
Sand	50	945
Slate	95	1040
Sand	195	1235
Slate	80	1315
Sand	25	1340
Slate	175	1515
Sand	25	1540
Slate	60	1600
Sand	25	1625
Slate	40	1665
Sand	95	1760
Slate	185	1945
Sand	67	2012
Slate	48	2060
Lime	5	2065
Slate	15	2080
Lime	5	2085
Slate	70	2155
Shelly	50	2205
Slate	42	2247
Sand	23	2270
Sand	13	2260

MUSKOGEE DISTRICT.

LOG OF WELL IN OLD TOWNSITE FIELD, MUSKOGEE POOL.

Formation	Thickness Feet	Depth Feet
Soil	15	15
Brown sand	10	25
Clay and gravel	35	60
Shale	40	100
Sand and salt water	20	120
Shale	100	220
Soapstone	230	450
Shale and shells	10	460
Sand	40	500
Gray shale	100	600
Salt water sand	90	690
Shale	40	730
Sand and lime	10	740
Shale	20	760
Salt water sand	15	775
Shale	15	790
Shale	75	865
Sand (smelled of oil)	10	875
Dark shale	100	975
Black shale and limestone	15	990
Shale	35	1025
Limestone	25	1060
Sand	5	1055
Blue slate	20	1075
Sand shale	25	1100

Drilled to 110 feet and quit with a full flow of salt water.

LOG OF WELL SARAH PERRYMAN No. 2, SEC. 8, T. 14 N., R. 18 E.

Formation	Thickness Feet	Depth Feet	Formation	Thickness Feet	Depth Feet
Slate	320	320	Sand	5	1395
Lime?	20	340	Slate	40	1435
Slate	130	470	Lime	50	1485
Lime	15	485	Sand	25	1515
Slate	240	725	Slate	65	1580
Lime	15	740	Lime	20	1600
Slate	85	825	Shale	5	1605
Broken sand	25	850	Lime, sandy	13	1618
Slate	320	1170	Slate	10	1628
Lime, hard	45	1215	Sand	24	1652
Slate	15	1230	Slate	5	1657
Lime, hard	15	1245	Sand	4	1661
Slate	30	1275	Slate	13	1684
Sand, water	30	1305	Sand	16	1700
Slate	85	1390			

PAWNEE COUNTY DISTRICT.
LOG OF WELL ON CLEVELAND TOWNSITE.

Formation	Thickness Feet	Depth Feet	Formation	Thickness Feet	Depth Feet
Red shale	180	180	White sandstone	100	700
White sandstone	25	205	Black shale	100	800
Red shale	35	240	White sandstone	20	820
White standstone	25	265	Black slate	200	1020
Red shale	195	460	Gray sandstone	195	1215
Limestone	25	485	Black slate	125	1340
White sandstone	10	495	Gray sandstone	15	1355
Red Shale	39	534	Black slate	215	1570
Limestone and sandstone	8	542	Oil sand	20	1590
Red shale	28	570	Gray standstone	15	1605
White sandstone	25	595	Second oil sand	10	1615
Red shale	5	600			

LOG OF WELL AT BLACKBURN.

Formation	Thickness Feet	Depth Feet	Formation	Thickness Feet	Depth Feet
Clay, yellow, soft	10	10	Sand, white, soft	8	685
Mud, red, soft	10	20	Red rock, soft	24	709
Lime, black, hard	12	32	Sand, white, soft	6	715
Shale, blue, soft	15	47	Shale, white, soft	16	731
Sand, white, soft (water)	15	62	Sand, white, soft (water)	40	771
Mud, red, soft	10	72	Shale, white, soft	51	822
Lime, white, hard	5	77	Red rock, soft	25	847
Red Rock, soft	35	112	Lime, white, hard	6	853
Sand, white, soft (water)	28	140	Sand, white, hard (little water)	10	863
Shale, white, soft	6	146	Shale, white, soft	54	917
Lime, white, hard	36	182	Sand, white, hard	35	952
Red rock, soft	30	212	Red rock, soft	10	962
Shale, blue, soft	40	252	Sand, white, hard (little wate)	30	992
Lime, white, hard	4	256	Shale, white, soft	28	1020
Red rock, soft	10	266	Red rock, soft	10	1030
Sand, white, soft (water at 285 feet)	36	302	Sand, white, soft (little water)	15	1045
Shale, white, soft	40	342	Red rock, soft	10	1055
Sand, white, soft	15	357	Sand, white, hard (hole full of water at 1085 feet)	215	1270
Shale, blue, soft	85	442	Shale, blue, soft	75	1345
Sand, white, hard (little salt water)	15	457	Lime, white, hard	35	1380
Shale, white, soft	70	527	Shale, white, soft	20	1400
Sand, white, soft (hole full of water at 530 feet)	85	612	Lime, white, hard	15	1415
Shale, white, soft	60	672	Shale, white, hard	35	1[illegible]0
Red rock, soft	5	677	Sand, white, hard	30	1480
			Shale, white, soft	35	1515
			Red rock, soft	8	1523

LOG OF BLACKBURN WELL—(Continued.)

Formation	Thickness Feet	Depth Feet
Shale, blue, soft	23	1546
Lime, white, hard	8	1554
Shale, brown, soft	131	1685
Sand, white, hard (water at 1730 feet)	55	1740
Shale, black, soft	170	1910
Sand, white, hard	15	1925
Shale, black, soft	10	1935
Lime, white, hard	6	1941
Shale, black, soft	10	1951
Sand, white, hard	12	1963
Shale, black, soft	22	1985
Sand, white, hard	25	2010
Shale, black, soft	140	2150
Lime, white, hard	5	2155
Shale, black, soft	10	2165
Lime, white, hard	45	2210
Shale, black, soft	6	2216
Lime, white, hard	10	2226
Shale, black, soft	8	2234
Lime, white, hard	9	2243
Shale, blue, soft	19	2262
Lime, white, hard	36	2298
Shale, black, soft	14	2312
Lime, white, hard	8	2320
Shale, white, soft	45	2365
Sand, white, soft (gas at 2370 feet; hole full of water at 2385 feet	30	2395
Lime, white, hard	10	2405
Shale, black, soft	25	2430
Shells, black, hard	20	2450
Shale, black, soft	30	2480
Sand, white, hard	6	2486
Shale, black, soft	8	2494
Lime, pink, hard	14	2508
Shale, white, soft	82	2590
Lime, white, hard	6	2596
Shale, black, soft	54	2650
Mud, red, soft	40	2690
Shale, white, soft	22	2712
Lime, hard, gray	124	2836

CUSHING DISTRICT.

Cushing Pool.

LOG OF WELL SUSANNA DACON, SEC. 16, T. 17 N., R. 7 F.

Formation	Thickness Feet	Depth Feet
Mud	40	40
Slate	60	100
Sand	20	120
Slate	20	140
Sand	45	185
Slate	55	240
Slate	60	300
Lime	20	320
Slate	20	340
Lime	10	350
Sand	40	390
Slate	10	400
Sand	15	415
Slate	10	425
Sand	15	440
Slate	205	460
Lime	10	470
Red rock	20	490
Lime	10	500
Red rock	10	510
Slate	10	520
Sand	20	540
Slate	10	550
Lime	25	575
Slate	5	580
Sand	35	615
Slate	50	665
Red rock	10	675
Slate	10	690
Lime	10	700
Shale	50	750
Sand	60	810
Slate	50	860
Sand	40	900
Shale	30	930
Lime	15	945
Slate	50	995
Sand	55	1050
Shale	50	1100
Lime	20	1126
Layton shell	15	1445
Layton Sand	15	1460
Gas sand	30	1490
First oil (200 bbls.)	25	1515
Lime	5	1520
Shale	55	1575
Jones sand (big gas)	35	1760
Shale	460	2220
Wheeler sand	30	2259
Shale	7	2257
Sand. Wheeler	96	2285
Shale	40	2325
Penn. sand (big gas)	95	2420
Slate	190	2610
Sand	20	2630
Slate	23	2653
Bartlesville sand	12	2665
Show oil at	--	----
*Sand	18	2683
Hard mud	11	2694
Good oil sand	41	**2735

*[illegible] 120 bbls over night in this sand.
**Entire production 250 bbls.

LOG OF WELL JEMIMIA RICHARDS No. 3, SW. OF THE N ½ OF SEC. 3, T. 17 N., R. 7 E.

Formation	Thickness Feet	Depth Feet
Sand	54	54
Slate	46	100
Lime	5	105
Slate	15	120
Red rock	48	168
Slate	12	180
Sand	85	205
Slate	29	234
Sand	23	257
Lime	5	262
Sand	22	284
Lime	10	294
Sand	6	300
Slate	5	305
Red rock	9	314
Slate	21	335
Lime	4	339
Slate	29	368
Red rock	22	390
Sand	20	410
Slate	5	415
Sand	20	435
Slate	24	461
Sand	13	474
Slate	15	489
Lime	21	510
Sand	20	530
Slate	4	534
Sand	12	546
Slate	22	568
Lime	8	576
Slate	14	590
Lime	30	620
Sand	7	627
Slate	8	635
Lime	12	647
Slate	10	657
Sand	33	690
Slate	20	710
Lime	10	720
Lime	9	729
Lime	3	732
Sand	17	749
Lime	4	753
Sand	7	760
Slate	16	776
Sand	24	800
Slate	3	803
Sand	7	810
Lime	2	812
Sand	6	818
Slate	62	880
Lime	5	885
Sand (water)	13	898
Slate	14	912
Sand	41	953
Slate	16	969
Lime	4	973
Sand	39	1012
Slate	13	1125
Slate	198	1326
Lime	6	1332
Slate	15	1347
Sand (Layton)	40	1387
Shale	5	1392
Slate	169	1561
Lime	4	1565
Sand (Cleveland	12	1577
Slate	444	2021
Wheeler sand	14	2035
Break	12	2047
Lime (2nd gas)	43	2090
Slate	106	2196
Lime	3	2199
Slate	101	2300
Sand (water)	1	2301
Slate	95	2396
Sand (gas)	15	2411
Slate	20	2431
Bartlesville sand	54	2485

LOG OF WELL SANDY FOX No. 4, NE. COR. NW. ¼ OF SEC. 10, T. 17 N., R. 4 E.

Formation	Thickness Feet	Depth Feet
Sand	20	20
Limy shells	10	30
Blue shale	40	70
Soft sand	50	120
Shale	40	160
Shell	4	164
Shale	36	200
Sand (water)	32	232
Blue shale	48	280
Lime shell	4	284
Sand	6	290
Yellow mud vein	12	302
Light blue shale	40	342
Red mud	13	355
Blue mud	6	361
Red mud	4	365
Shell and sand	6	371
Red mud	29	400
Blue shale	70	470
Sand and gravel	10	480
Light blue shale (blue mud vein)	12	492
Sand shale	10	502
Blue mud	18	520
Sand and shell—hard	12	532
Blue shale	28	560
Water, sand and shell—water	20	580
Blue shale	15	595
Shell and sand	12	607
Blue mud vein (cave)	12	619
Sandy shale	4	623
Sand	29	652
Blue mud	20	672
Lime	8	680
Blue mud or shale	175	855
Shell	5	860
Slate	5	865
Shell	5	870
Slate	5	875
Shell	5	880
Slate	20	900
Sand	5	905
Black shale	30	935
Water gravel	3	938

LOG OF SANDY FOX WELL No. 4—(Continued)

Formation	Thickness Feet	Depth Feet
Blue shale	7	945
Shale	315	1260
Shelly (gas)	20	1280
Lime	10	1290
Blue shale	29	1319
Lime shell	2	1321
Blue shale	17	1339
Lime shell	2	1341
Layton gas sand	9	1350
Slate	10	1360
Sand	15	1375
Slate	125	1500
Black shale	50	1550
White slate	33	1583
Jones sand (gas)	50	1633
Slate	37	1670
Lime (gas)	5	1675
Blue shale	205	1880
Sand (second gas)	25	1905
Blue shale	118	2023
Lime shell	13	2036
Lime shell (top of Wheeler)	59	2094
Slate	40	2135
Sand (gas)	135	2170
Shale	20	2195
Lime	5	2200
Blue shale	45	2245
Sand (second gas)	20	2265
Slate	80	2345
Lime	5	2350
Slate	10	2360
Lime	5	2365
Slate	40	2405
Shell	5	2410
Shale (black)	52	2462
White, hard, gas sand (top of Bartlesville)	5	2467
Gray sand	16	2483
Gray sand, fine	6	2489
More gas (first flow)	13	2502
Broken sand	10	2512
Big pay	6	*2513

*First 24 hours, 964 bbls. Tools in hole. Entire production, 1,060 bbls.

KAY COUNTY DISTRICT.

Newkirk Pool.

LOG OF HAYES WELL No. 1, SE. ¼ OF SEC. 15, T. 27 N., R. 3 E.

Formation	Thickness Feet	Depth Feet
Lime	25	25
Rock	65	90
Mud	24	114
Lime	23	137
Sandy lime	46	183
Red rock	22	205
Lime	25	230
Mud, red	25	255
Lime	25	280
Red rock	60	340
Lime	160	500
Slate	5	505
Lime	5	510
Slate	25	535
Lime	15	550
Slate	10	560
Lime	3	563
Slate	37	600
Lime	10	610
Slate	20	630
Lime	10	640
Slate	55	695
Lime	15	710
Slate	70	780
Lime	20	800
Slate	35	835
Lime	15	850
Slate	30	880
Sandy Lime	10	890
Slate	10	900
Lime	10	910
Slate	35	945
Lime	5	950
Slate	5	955
Lime	5	960
Slate	8	968
Red Rock	9	977
Slate	5	982
Sand	23	1005
Slate	15	1020
Sand	42	1062
Slate	53	1115
Lime	28	1143
Slate	7	1150
Lime	43	1193
Slate	3	1196
Lime	19	1215
Slate	15	1230
Lime	15	1245
Red rock	5	1250
Lime	35	1285
Slate	5	1290
Lime	10	1300
Slate	45	1345
Sandy Lime	15	1360
Sand	10	1370
Lime	30	1400
Slate	10	1310
Sand	26	1436
Slate	4	1440
Lime	10	1450
Slate	55	1505
Lime	5	1510
Slate	15	1525
Lime	20	1545
Slate	80	1625
Sand Water	5	1630
Lime	20	1650
Sand	5	1655
Slate	5	1660
Sand	20	1680
Lime	5	1685
Sand	9	1694
Lime	41	1735

LOG OF HAYS WELL No. 1—(Continued)

Formation	Thickness Feet	Depth Feet
Slate	35	1770
Shale	5	1775
Lime	5	1780
Sand	35	1815
Lime	20	1835
Slate	65	1900
Sand	8	1908
Shale	12	1920
Sand	10	1930
Shale	65	1995
Slate	65	2060
Sand	20	2080
Lime	50	2130
Sand	15	2145
Lime	10	2155
Shale	30	2185
Sand	50	2235
Shale	10	2245
Slate	10	2255
Shale	10	2265
Slate	10	2275
Sand	10	2285
Slate	10	2295
Shale	10	2305
Slate	5	2310
Sand	128	2438
Lime	15	2453
Sand	4	2457
Slate	6	2463
Sand	5	2468
Slate	12	2480
Shale	30	2510
Lime	10	2520
Slate	33	2553
Shale	17	2570
Slate	30	2600
Shale	44	2644
Lime	16	2660
Slate	15	2675
Lime	140	2815
Shale	7	2822
Lime	3	2825
Slate	25	2850
Lime	18	2868
Slate	4	2872
Lime	8	2880
Slate	10	2890
Lime	22	2912
Slate	6	2918
Lime	2	2920
Slate	5	2925
Lime	7	2932
Slate	13	2945
Lime	15	2960
Slate	5	2965
Lime	5	2970
Slate	18	2988
Lime	5	2993
Slate	80	3073
Shell	3	3076
Sand	5	3081
Oil & Gas	4	3085
Oil Sand	6	3091
Sand	3	3094

LOG OF SOUTH CRONAN WELL No. 1, SEC. 2, T. 27 N., R. 3 E.

Formation	Thickness Feet	Depth Feet
Soil	1	1
Lime	25	26
Red Rock	38	63
Lime	5	68
Red Rock	2	70
Lime	2	72
Shale	10	82
Lime	15	97
Shale	24	121
Lime	25	146
Shale	20	166
Water Sand	8	174
Shale	31	205
Lime	5	210
Shale	40	250
Lime	10	260
Shale	32	292
Sand Gas	18	310
Shale	40	350
Lime	5	355
Shale	15	370
Lime	5	375
Lime	200	575
Shale	40	615
Lime	5	620
Shale	3	623
Shale	95	800
Sand Water	5	805
Shale	5	810
Lime	15	825
Shale	35	860
Sand	15	875
Shale	15	890
Lime	25	915
Shale	58	973
Lime	4	977
Shale	10	987
Lime	12	999
Shale	9	1008
Sand Oil Sand	8	1016
Shale	8	1024
Sand Oil	6	1030
Sand	18	1098
Shale	10	1108
Shale	38	1080
Sand	18	1089
Shale	10	1198
Lime	14	1122
Shale	10	1132
Lime	63	1195
Shale	9	1204
Lime	45	1249

LOG OF SOUTH CRONAN WELL No. 1—(Continued)

Formation	Thickness Feet	Depth Feet	Formation	Thickness Feet	Depth Feet
Lime	22	645	Shale	8	1338
Shale	55	700	Sand Water & Oil	62	1400
Lime	5	705	Shale	30	1430
Sand Water	10	1259	Sand	30	1460
Shale	4	1263	Shale	20	1480
Lime	6	1269	Lime	10	1490
Shale	26	1295	Shale	10	1500
Sand	35	1330	Red Rock	10	1510

Ponca City Pool.

LOG OF MARGARET PRIMEAUX WELL No. 1, SEC. 4, T. 25 N., R. 2 E.

Formation	Thickness Feet	Depth Feet	Formation	Thickness Feet	Depth Feet
Soil	4	4	Slate	2	760
Clay	40	44	Lime	25	785
Sand and gravel	6	50	Slate	74	859
Lime	20	70	Shell	9	868
Red Rock	45	115	Slate	35	903
Shell	5	120	Shell	3	906
Red rock	40	160	Slate	26	932
Lime	5	165	Lime	3	935
Slate	10	175	Sand	15	950
Red Rock	59	234	Slate	25	975
Sand (Gas)	20	254	Lime	10	985
Red Rock	10	264	Slate	60	1045
Slate	5	269	Shale	15	1060
Lime	5	274	Lime	10	1070
Slate	13	287	Slate	60	1130
Red Rock	12	299	Shale	15	1145
Lime	46	345	Slate	75	1220
Red Rock	20	365	Lime	15	1235
Sand (Gas)	12	377	Slate	25	1260
Slate	2	379	Lime	15	1275
Lime	4	383	Red Rock	4	1279
Slate	30	413	Lime	2	1281
Red Rock	42	455	Slate	10	1291
Lime	10	465	Lime	15	1306
Red Rock	2	467	Slate	12	1318
Lime	6	473	Lime	2	1320
Red Rock	39	542	Sand (Gas)	12	1332
Sand (Gas)	12	554	Slate	20	1352
Red Rock	18	572	Lime	10	1362
Lime	4	576	Slate	35	1397
Slate	17	593	Lime	15	1412
Lime	47	640	Slate	10	1422
Slate	5	645	Lime	8	1430
Red Rock	6	651	Slate	5	1435
Slate	8	659	Lime	8	1443
Lime	10	669	Slate	17	1460
Red Rock	10	679	Lime	27	1487
Lime	26	705	Slate	6	1493
Slate	8	713	Lime	3	1496
Lime	10	723	Slate	10	1506
Sand	20	743	Sand	20	1526
Break	2	745	Slate	4	1530
Sand, Little Gas	4	749	Oil Sand	19	1549
Lime	9	758			

LOG OF MOLLIE MILLER WELL No. 9, SEC. 9, T. 25 N., R. 2 E.

Formation	Thickness Feet	Depth Feet
Surface	10	10
Red Rock	30	40
Quick Sand	5	45
Red Rock	50	95
Blue Mud	15	110
Lime	6	116
Mud	10	126
Lime	6	132
Red Rock	8	140
Lime	4	144
Red Rock	6	150
Mud	15	165
Lime	5	170
Mud	5	175
Lime	25	200
Mud	5	205
Red Rock	20	225
Lime	5	230
Red Rock	25	255
Mud	10	265
Lime	22	287
Mud	8	295
Lime	20	315
Red Rock	40	355
Lime	5	360
Red Rock	5	365
Lime	5	370
Red Rock	130	505
Sand	40	545
Red Rock	5	550
Sand	34	584
Mud	10	594
Lime	18	612
Mud	3	615
Lime	1	616
Sand	9	625
Mud	30	655
Red Rock	11	666
Lime	69	735
Slate	20	755
Lime	10	765
Slate	80	845
Lime	5	850
Mud	10	860
Lime	15	875
Mud	20	895
Lime	5	900
Broken Lime	35	935
Sand Water	5	940
Slate	46	986
Lime	6	992
Mud	23	1015
Lime	5	1020
Slate	30	1050
Lime	25	1075
Slate	20	1095
Lime	10	1105
Hard Coal	2	1107
Slate	13	1120
Lime	5	1125
Shale	10	1135
Lime	15	1150
Slate	50	1200
Lime	15	1215
Slate	25	1240
Lime	10	1250
Slate	5	1255
Red Rock	5	1260
Slate	20	1280
Lime	10	1290
Shale	18	1308
Sand	29	1337
Slate	20	1357
Lime	5	1362
Slate	20	1382
Sand	5	1387
Slate	13	1400
Lime	10	1410
Slate	15	1425
Lime	10	1435
Slate	25	1460
Lime	30	1490
Slate	15	1505
Red Rock	15	1520
Ponca Sand, Gray (Oil)	15	1535
Slate	35	1570
Lime	20	1590
Slate	15	1605
Red Rock	25	1630
Sand	20	1650
Sand White	20	1670
Slate	5	1675
Lime	15	1690
Slate	20	1710
Sand	10	1720
Slate	25	1745
Sand	20	1765
Lime	15	1780
Shale	53	1833
Sand, Show Oil	15	1848
Shale	22	1870
Sand	15	1870
Sand	15	1885
Sand	53	1988
Slate	1	1989
Lime	54	2043
Slate	104	2147
Sand	93	2240
Slate	350	2590
Lime	45	2635
Shale	20	2655
Lime	45	2700
Lime	25	2725
Shale	10	2735
Sand	40	2775
Lime	5	2780
Shale	70	2850
Slate	137	2987
Lime	103	3090
Slate	70	3160
Lime	20	3180
Shale	32	3212
Lime	10	3222
Sand	23	3245
Shale	8	3253
Lime	12	3265
Shale	5	3270
Lime	60	3330
Slate	30	3360
Shale	40	3400
Slate	50	3450
Shale	20	3470
Slate	10	3480
Shale	20	3500

LOG OF MOLLIE MILLER WELL No. 9—(Continued)

Formation	Thickness Feet	Depth Feet	Formation	Thickness Feet	Depth Feet
Rock	50	3550	Lime	115	3840
Lime	3	3553	Slate	2	3842
Shale	32	3585	Lime	28	3870
Slate	5	3590	Shale	20	3890
Shale	10	3600	Lime	3	3893
Shale	10	3610	Slate	15	3908
Sand	14	3624	Lime	2	3910
Lime	26	3650	Slate	6	3916
Lime	50	3700	Lime	13	3929
Lime	25	3725	Sand (Oil)		

Blackwell Pool.

LOG OF GUS SWENSON No. 1, NE. ¼, NE. ¼ SEC. 32, T. 29 N., R. 1 E.

Formation	Thickness Feet	Depth Feet	Formation	Thickness Feet	Depth Feet
Soil	5	5	Lime	20	1230
Clay Water	9	14	Slate	60	1290
Shale	12	26	Lime	10	1300
Gypsum	4	30	Slate	120	1420
Shale	16	46	Lime	24	1444
Gypsum	8	54	Sand (Water & Gas)	36	1480
Shale	25	79	Lime	20	1500
Lime	3	82	Shale	110	1610
Shale	19	101	Lime	20	1630
Lime	4	105	Shale	10	1640
Red Rock	18	123	Lime	3	1643
Shale	140	263	Shale	97	1740
Red Rock	34	297	Lime	10	1750
Shale	30	327	Sand Gas	25	1775
Lime	5	332	Red Rock	15	1790
Shale	14	346	Shale	10	1800
Lime	4	350	Sand Water	25	1825
Sand Gas	20	370	Shale	15	1840
Shale	65	435	Red Rock	60	1900
Lime Sand Water	7	442	Lime	40	1940
Red Rock	15	457	Shale	20	1960
Shale	41	498	Sand Oil Showing	25	1985
Lime	3	501	Sand Water	2	1987
Slate	26	527	Slate	13	2000
Lime	10	537	Lime	7	2007
Shale	20	557	Slate	83	2090
Sand Gas	33	590	Lime	10	2100
Shale	22	612	Red Rock	10	2110
Lime	7	619	Lime	105	2215
Slate	21	640	Slate	63	2278
Red Rock	21	661	Sand Oil Showing	15	2293
Shale	6	667	Slate	5	2298
Slate	2	669	Sand Water	12	2310
Lime	5	674	Slate	345	2655
Shale	41	715	Sand Oil	32	2687
Sand (Blackwell Gas?)	27	742	Sand Water	63	2750
Shale	28	770	Slate	5	2755
Sand Water	26	796	Lime	10	2765
Shale	80	876	Sand Water	15	2780
Lime	9	885	Lime	20	3000
Red Rock	17	902	Shale	50	3050
Shale	18	920	Sand Oil Showing	20	3070
Sand Gas	22	942	Lime	130	3200
Lime	3	945	Shale	100	3300
Sand Water	55	1000	Sand Water	30	3330
Red Rock	30	1030	Slate	25	3355
Shale	70	1100	Sand Gas	10	3365
Lime	15	1115	Oil Sand (still in sand)	20	3385
Shale	95	1210			

LOG OF SIMMONS WELL No. 1, NW. ¼, SW. ¼, SEC. 8, T. 28 N., R. 1 E.

Formation	Thickness Feet	Depth Feet
Shale	85	85
Lime	5	90
Shale	380	470
Gas Sand (show gas)	20	490
Shale	135	625
Red Rock	135	760
Lime Shell	5	765
Gas Sand	35	800
Lime	30	830
Shale	95	5
Lime	22	947
Shale	38	985
Slate	65	1050
Lime	12	1062
Slate	18	1080
Lime	150	1230
Slate	45	1275
Sandy	150	1425
Slate	55	1480
Lime	6	1486
Sand Water	34	1520
Slate	45	1565
Lime	35	1600
Shale	45	1645
Lime	15	1660
Shale	120	1780
Lime Show Gas	5	1785
Sand	35	1820
Red Rock	5	1825
Shale	15	1840
Lime	16	1856
Sandy Shale	34	1890
Lime	60	1950
Red Rock	10	1960
Slate	5	1965
Red Rock	50	2015
Sand	15	2030
Shale	40	2070
Lime	15	2085
Sand	15	2100
Lime	10	2110
Shale	125	2235
Lime	5	2240
Slate	46	2286
Lime	8	2294
Shale	6	2300
Stonaker Sand	55	2355
Water Sand	35	2390
Slate	15	2405
Lime	3	2408
Slate	117	2525
Shelly Sand	5	2530
Slate	190	2720
Lime	2	2722
Sand, Gas, Oil, Water	48	2770
Water Sand	30	2800
Slate	5	2805
Lime	5	2810
Slate	70	2880
Sand	10	2890
Lime	5	2895
Slate	100	2995
Lime	25	3020
Slate	10	3030
Sand & Shale (oil)	32	3062
Lime	8	3070
Sandy Lime	30	3100
Sand	5	3105
Lime	47	3152
Shale	6	3158
Lime	7	3165
Shale	5	3170
Lime	30	3200
Shale	55	3255
Shale.	75	3330
Sand Gas	8	3338
Lime	40	3378
Sandy Lime	22	3400
Sandy Slates	6	3406
Shell	2	3408
Sand Oil	5	3413
Sand	5	3418
Shell	1	3419
Sand	27	3446
Slate	16	3462
Shell	2	3464
Lime & Slate	7	3471

LOG OF WELSH WELL No. 5, SEC. 20, T. 28 N. R. 1 E.

Formation	Thickness Feet	Depth Feet
Slate	40	40
Gypsum	10	50
Lime	10	60
Broken Lime	25	85
Lime	95	180
Slate	30	180
Slate	30	210
Red Rock	35	245
Slate	25	270
Slate	90	370
Red Rock	29	399
Lime	51	450
Slate	20	470
Sandy Lime	20	490
Red Rock	20	510
Shells	15	525
Red Rock	5	530
Shell	20	550
Lime	20	570
Slate	10	580
Red Rock	50	630
Lime	10	640
Red Rock	40	680
Shell	20	700
Sand Gas	70	770
Lime	60	830
Slate	20	850
Lime	10	860
Slate	20	880
Lime	95	975
Slate	20	995
Lime	10	1005
Slate	65	1070
Lime	10	1080

LOG OF WELSH WELL No. 5—(Continued)

Formation	Thickness Feet	Depth Feet	Formation	Thickness Feet	Depth Feet
Slate	48	1128	Lime	30	1684
Lime	37	1165	Shale	12	1696
Slate	53	1218	Sandy Lime	7	1703
Lime	10	1228	Slate	20	1723
Slate Oil	190	1418	Lime	12	1735
Lime	15	1433	Break	14	1749
Slate	22	1455	Hole reduced at 1743		
Lime	8	1463	Shell	2	1751
Slate	22	1485	Slate	5	1756
Lime	25	1510	Top Sand	10	1766
Slate	30	1540	Slate	29	1795
Lime	10	1550	Slate	15	1810
Sandy Lime Show Oil	45	1595	Lime	25	1835
Slate	40	1635	Slate	70	1905
Sand Gas 1660	9	1644	Red Rock	10	1915
Slate	10	1654	Sand Oil		

Garber Pool.

LOG OF HOY WELL No. 1, SEC. 25, T. 22 N., R. 4 W.

Formation	Thickness Feet	Depth Feet	Formation	Thickness Feet	Depth Feet
Clay	40	40	Red Rock	25	675
Water Sand	15	55	Lime	3	678
Red Rock	145	200	Red Rock	22	700
Shale	30	230	Lime	3	703
Red Rock	10	240	Break	17	720
Shale	60	300	Lime	13	733
Red Rock	20	320	Shale	27	760
Shale	80	400	Shells	16	776
Red Rock	25	425	Shale	44	820
Shale	25	450	Shell	10	830
Red Rock	40	490	Shale	5	835
Shale	30	520	Red Rock	15	850
Red Rock	30	550	Sand Gas	30	880
Shale	40	590	Red Rock	10	890
Lime	3	593	Sand	70	960
Shale	7	600	Red Rock	90	1050
Red Rock	30	630	Sand, Oil and Gas	50	1100
Lime	3	633	Red Rock	38	1138
Shale	17	650	Sand Oil	18	1156

LOG OF DIVELY WELL No. 10, SEC. 24, T. 22 N., R. 4 W.

Formation	Thickness Feet	Depth Feet	Formation	Thickness Feet	Depth Feet
Red Rock	52	52	Red Rock	31	688
Water Sand	8	60	Lime	4	692
Shale	7	67	Shale	12	704
Red Rock	127	194	Lime	40	744
Shale	161	255	Shale	20	764
Shale Blue	45	300	Lime	8	772
Brown Shale	30	330	Shale	12	784
Blue Shale	50	380	Lime	8	792
Red Rock	10	390	Shale	6	798
Shale	32	422	Lime	4	802
Red Rock	18	440	Red Rock	22	824
Lime	52	492	Lime	5	829
Red Rock	52	544	Shale	17	846
Shale	50	594	Sand Gas	5	851
Lime	2	596	Lime	10	861
Red Rock	20	616	Red Rock	30	891
Shale	38	654	Lime	3	894
Lime	3	657	Sandy Shell	10	904

LOG OF DIVELY WELL No. 10.—(Continued)

Formation	Thickness Feet	Depth Feet
Sand Gas	16	920
Shale	10	930
Red Rock	35	965
Lime	2	967
Brown Shell	8	975
Sand Lime	5	980
Shale	10	990
Red Rock	50	1040
Shale	5	1045
Lime	7	1052
Blue Shell	8	1064
Red Rock	10	1074
Lime	3	1077
Shale	6	1083
Red Rock	25	1108
Hoy Sand	14	1122
Red Rock	10	1132
Sand	20	1152
Shale	5	1157
Red Rock	8	1165
Shale	10	1175
Lime Shell	25	1200
Shale	6	1206
Red Rock	24	1230
Lime	4	1234
Shale	4	1238
Red Rock	6	1244
Lime	4	1248
Sand	9	1257
Water Sand	9	1266
Shale	9	1275
Lime	17	1292
Shale	7	1299
Red Rock	31	1330
Sand Water	20	1350
Hole full of water		
Blue Shale	8	1358
Red Rock	23	1381
Lime	2	1383
Red Rock	58	1441
Hotson Sand	3	1444
First Oil Sand		1444
Total Depth		1452

LOG OF WHITNEY WELL No. 1, SEC. 18, T. 22 N., R. 3 W.

Formation	Thickness Feet	Depth Feet
Soil	12	12
Quick Sand	13	25
Red Rock	75	00
Sand	10	110
Red Rock	210	320
Blue Shale	80	400
Shale	120	520
Red Rock	10	530
Light Shale	90	620
Red Rock	30	650
Shale	10	660
Red Rock	40	700
Light Shale	40	740
Lime	5	745
Red Rock	55	800
Lime	5	805
Light Shale	35	840
Shale	145	985
Red Rock	15	1000
Shale	35	1035
Sand	20	1055
Red Rock	35	1090
Lime	5	1095
Red Rock	5	1100
Sand	15	1115
Shale	10	1125
Sand	10	1135
Red Rock	95	1230
Sand	41	1271
Red Rock	64	1335
Sand	25	1360
Shale	30	1390
Sandy Lime	30	1420
Sand	60	1480
Lime	5	1485
Red Rock	63	1548
Lime	10	1558
Red Rock	37	1595
Broken Shells	15	1610
Red Rock	50	1660
Lime	20	1680
Shale	45	1725
Lime	5	1730
Red Rock	35	1765
Shale	30	1795
Lime	165	[illegible]
Shale	100	2050
Lime	5	2055
Shale	185	2240
Red Rock	40	2280
Lime	17	2297
Shale	56	2353
Lime	29	2382
Lime	5	2387
Sandy Shale	15	2402
Sandy Lime	5	2407
Shale	10	2417
Lime	10	2427
Red Rock	10	2437
Sandy Shale	23	2460
Light Shale	10	2470
Blue Shale	40	2510
Lime	10	2520
Shale	30	2550
Lime	10	2560
Shale	20	2580
Sand	10	2590
Shale	5	2595
Sand	45	2640
Shale	41	[illegible]
Sand	14	2695
Shale	15	2710
Lime	[illegible]	2730
Shale	5	2735
Lime	5	2740
Shale	5	2745
Sand	20	2765
Shale	5	2770

LOG OF WHITNEY WELL No. 1, SEC. 18, T. 22 N., R. 3 W.—(Continued)

Formation	Thickness Feet	Depth Feet
Shale Blue	25	2795
Sand	40	2835
Sand Water	50	2885
No record		
Sand		3175
Slate	52	3227
Lime	2	3229
Slate	6	3235
Sand Water	43	3278
Slate	3	32[illegible]1
Red Rock	9	3290
Slate	31	3321
Lime	7	3328
Slate	5	3333
Lime	5	3338
Slate	22	3360
Sand	40	3400
Slate	108	3508
Shell	4	3512
Slate	8	3520
Sand	50	3570

Billings Pool.

LOG OF HOOVER WELL No. 1, SEC. 22, T. 23 N., R. 2 W.

Formation	Thickness Feet	Depth Feet
Soil	6	6
Lime	24	30
Water Sand	4	34
Slate	16	50
Red Rock	10	60
Slate	50	110
Red Rock	130	240
Slate	10	250
Red Rock	15	265
Lime	4	269
Red Rock	46	315
Shell	10	325
Red Rock	5	330
White Shale	8	338
Red Rock	17	355
Slate	10	365
Red Rock	15	380
Lime	70	450
Slate	42	492
Red Rock	28	520
Lime	15	535
Red Rock	25	560
Hard Shell	10	570
Sand (Gas)	12	582
Red Rock	38	620
Lime	5	625
Sand	15	640
Red Rock	56	696
Shale	19	715
Red Rock	25	740
Sand	15	755
Slate	10	765
Lime	42	807
Red Rock	23	830
Sand (Gas)	12	842
Red Rock	18	860
Lime	10	870
Red Rock	14	884
Sand (gas)	21	905
Lime	10	915
Red Rock	112	1027
Sand (gas)	20	1047
Slate	2	1049
Lime	17	1066
Red Rock	64	1130
Lime	6	1136
Red Rock	14	1150
Sand, salt water	20	1170
Slate	25	1195
Lime	17	1218
Red Rock	52	1270
Lime	30	1300
Slate	15	1315
Lime	75	1390
Slate	5	1395
Lime	81	1476
Sand (gas)	69	1545
Slate	25	1570
Shells	30	1600
Slate	30	1630
Slate	76	1706
Shell	10	1716
Red Rock	12	1728
Slate	10	1738
Lime	9	1747
Red Shale	3	1750
Red Rock	46	1796
Sand water	16	1812
Sandy lime	16	1828
Slate	6	1834
Lime	27	1861
Sand	7	1868
Slate	32	1900
Red Shale	3	1903
Dark Shale	45	1948
Slate	5	1953
Lime	15	1968
Slate and Shells	20	1988
Lime	3	1991
Slate	9	2000
Lime	10	2010
Red Shale	10	2020
Sand (oil)	16	2036
Dark Shell	51	2087
Lime	2	2089
Shale	25	2114
Lime	1	2115
Shale	9	2124
Sand (oil and gas)	10	2134

LOG OF J. W. NEIL WELL No. 1, E. ½, NW. ¼, SEC. 14, T. 23 N., R. 2 W.

Formation	Thickness Feet	Depth Feet
Soil	30	30
Gravel	10	40
Slate	10	50
Slate, blue	60	110
Red Rock	230	340
Lime	5	345
Slate	30	375
Lime	15	390
Slate	20	410
Lime	10	420
Slate	20	440
Red Rock	10	450
Lime	10	460
Red Rock	55	515
Slate	15	530
Sand	10	540
Slate	5	545
Red mud	30	575
Shale	5	580
Slate	15	595
Lime	5	600
Red Rock	60	660
Shale	15	675
Red Rock	15	690
Lime water	20	710
Slate	15	725
Lime	30	755
Red Rock	40	795
Lime	15	810
Red Rock	35	845
Mud	5	850
Shale	25	875
Red mud	20	895
Mud	20	915
Red mud	43	958
Lime	2	960
Red Rock	35	995
Sand	24	1019
Red Rock	6	1025
Lime	10	1035
Shale	20	1055
Red Rock	5	1060
Sand and water	28	1088
Mud	8	1096
Red Rock	22	1118
Lime water	4	1122
Shale	28	1150
Lime	2	1152
Sand	3	1155
Slate	20	1175
Lime	5	1180
Slate	5	1185
Lime	5	1190
Mud	45	1235
Red Rock	3	1238
Lime	1	1239
Break	2	1241
Sand	15	1256
Lime	4	1260
Sand water	13	1273
Slate	2	1275
Lime	38	1313
Slate	9	1322
Lime	5	1327
Sand	20	1347
Slate	3	1350
Lime	10	1360
Slate	15	1375
Lime	10	1385
Lime	15	1400
Shale	35	1435
Sandy shale	20	1455
Shale	15	1470
Lime	15	1485
Shale	35	1520
Sandy slate	10	1530
Slate	55	1585
Slate and lime	5	1590
Sandy lime	10	1600
Shale	18	1618
Sand	4	1622
Shale	8	1630
Slate and sand	75	1705
Lime	3	1708
Red Rock	12	1720
Lime	25	1745
Shale	25	1770
Lime	5	1775
Red Rock	20	1795
Lime	5	1800
Sand water	25	1825
Shale	5	1830
Lime	15	1845
Slate	5	1850
Lime	8	1858
Shale	35	1893
Lime	7	1900
Sand	10	1910
Slate	30	1940
Lime	10	1950
Shale	26	1976
Sand	7	1983
Slate	5	1988
Lime	7	1995
Slate	5	2000
Red Rock	10	2010
Sand	18	2028
Shale	4	2032
Lime	8	2040
Slate	30	2070
Lime	36	2106
Shale	7	2113
Red Rock	7	2120
Shell	1	2121
Slate	17	2138
Sand	34	2172
Shale	5	2177
Sand water	16	2193
Shale	7	2200
Lime	1	2201
Shale	43	2244
Sandy lime	20	2264
Slate	31	2295
Shale	8	2303
Lime	2	2305
Slate	5	2310
Sand water	10	2320
Slate	10	2330
Water sand	24	2354
Shale	3	2357
Sand	18	2375
Shale	35	2410
Sand	17	2427
Shale	39	2466

LOG OF J. W. NEIL WELL No. 1—(Continued)

Formation	Thickness Feet	Depth Feet	Formation	Thickness Feet	Depth Feet
Lime	22	2488	Sand	30	2780
Slate	27	2515	Slate	8	2788
Lime	8	2523	Lime	5	2793
Red Rock	14	2537	Slate	20	2813
Slate	3	2540	Gray and hard sand	8	2821
Lime	10	2550	Slate	10	2831
Shale	7	2557	Gray sand	3	2834
Water sand	8	2565	Water sand	121	2955
Slate	115	2672	Slate	1	2956
Lime	4	2676	Lime	14	2970
Shale	1	2677	Sand	20	2990
Lime	2	2679	Lime	5	2995
Sand and broken lime	9	2688	Sand and lime	17	3012
Slate	21	2709	Broken lime and sand	8	3020
Water sand	33	2742	Broken sand and lime	11	3031
Slate	8	2750			

Barnes Pool.

LOG OF BARNES WELL No. 1, NW. ¼, NW. ¼, SEC 15, T. 23 N., R. 3 W

Formation	Thickness Feet	Depth Feet	Formation	Thickness Feet	Depth Feet
Red Rock	0	195	Sand	15	1235
Shale	5	200	Shale	10	1245
Shale	25	225	Shell	15	1260
Red Rock	10	235	Shale	10	1270
Shale	215	450	Red Rock	35	1305
Red Rock	5	455	Sand water	10	1315
Shale	95	550	Red Rock	10	1325
Red Rock	15	565	Shell	5	1330
Shale	35	600	Red Rock	.5	1335
Red Rock	65	665	Shell	5	1340
Lime	3	668	Sand	30	1370
Shale	57	725	Red Rock	30	1400
Shell	5	730	Shell	5	1405
Shale	70	800	Shale	30	1435
Shell	10	810	Shell	45	1480
Shale	5	815	Red Rock	30	1510
Shell	10	825	Shale	10	1520
Shale	10	835	Shell	5	1525
Shell	5	840	Shale	5	1530
Shale	10	850	Shell	5	1535
Shell	40	890	Red Rock	45	1580
Shale	15	905	Shell	5	1585
Shell	10	915	Shale	20	1605
Shale	5	920	Shell	35	1640
Red Rock	25	945	Red Rock	20	1660
Shale	15	960	Shale	30	1690
Shell	15	975	Shell	65	1755
Red Rock	50	1025	Shale	5	1760
Shell	30	1055	Shell	40	1800
Sand water	15	1070	Shale	60	1860
Red Rock	5	1075	Shell	15	1875
Shale	10	1085	Shale	75	1950
Shell	40	1125	Shell	10	1960
Shale	40	1165	Shale	40	2000
Shell	20	1185	Shell	20	2020
Red Rock	30	1215	Shell	9	2029
Shell	5	1220	Sand oil	8	2037

WOODS COUNTY.

LOG OF J. P. DRAKE WELL, No. 1, SEC. 8. T. 27 N., R. 16 W.

Formation	Thickness Feet	Depth Feet
Red Sand	0	20
Red Rock	20	90
Gypsy Rock	90	125
Red Rock	125	370
Gypsy Rock	370	380
Red Rock	380	530
Gypsy Rock	530	540
Red Rock	540	550
Sand	560	570
Red Rock	570	605
Gypsy Rock	605	615
Red Rock	615	745
Soft red sand	745	755
Red Rock	765	1020
Salt Rock	1020	1030
Red Rock	1030	1035
Salt Rock	1035	1045
Red Rock	1045	1050
Salt Rock	1050	1170
Red Rock	1170	1595
Blue slate	1595	1685
Flint shell	1685	1690
Blue slate	1690	1850
Lime	1850	1860
Sand and salt rock	1860	1900
Salt Rock	1900	1940

Formation	Thickness Feet	Depth Feet
Blue slate	2040	2056
Lime	2056	2062
Salt Rock	2062	2100
Lime	2100	2115
Salt Rock	2115	2230
Lime	2230	2250
Salt Rock	2250	2300
Lime	2300	2340
Blue slate	2340	2350
Lime	2350	2590
Sand	2590	2625
Lime	2625	2665
Sand	2665	2700
Lime	2700	2735
Sand	2735	2760
Lime	2760	2860
Sand	2860	2900
Lime	2900	2990
Black slate	2990	2930
Red Rock	2930	2935
Red Rock	3030	3035
Lime	3035	3100
Slate and shell	3100	3110
Lime	3110	3160
Sand	3160	3185
Lime	3185	3218

EAST CENTRAL OKLAHOMA DISTRICT.

LOG OF GYPSY OIL CO., WELL No. 1, SE. COR. NW. ¼, SEC. 6, T. 6 N., R. 14 E.

Formation	Thickness Feet	Depth Feet
Soil	0	4
Sand	38	42
Slate	18	60
Sand	20	80
Slate	84	164
Sand	6	170
Slate	40	210
Sand	30	240
Brown shale	20	260
Slate	20	280
Black shale	85	365
Black slate, hard shells	1	366
Sandy shale, gray	69	435
Sand, hard	10	445
Soft white sand	10	455
Slate	25	480
Black shale	20	500
Slate, white	20	520
Sand	15	535
Slate, white	15	550
Slate, black	50	600
Sand (2M gas 665)	55	655
Broken sand and slate	30	685
Slate	15	700
Lime	20	720
Slate	5	725
Sand	45	770
Slate, dark	230	1000
Slate, white	22	1022
Shell, lime	8	1030
Slate, black	10	1040
Sand	30	1070
Slate, white	150	1220
Slate, black	5	1225
Shell	10	1235
Slate	8	1243

Formation	Thickness Feet	Depth Feet
Lime shell	3	1246
Slate, white	18	1264
Lime shell	3	1267
Slate and shells	65	1332
Sand	28	1360
Slate, black (caving 1385-1400 feet)	40	1400
Coal	2	1402
Slate, black	18	1420
Slate, white	30	1450
Shale, brown	40	1490
Shale, black	41	1531
Slate	17	1548
Sand	12	1560
Slate, blue	20	1580
Shale, black	85	1665
Coal	3	1668
Shale, black	32	1700
Sand, soft, broken	15	1715
Sand	13	1728
Slate, white	50	1778
Slate, black	172	1950
Sandy lime	5	1955
Slate, black	241	2196
Sand, broken	21	2217
Shale, black	40	2257
Sand, little gas	33	2290
Slate, black	313	2603
Coal (1-2 boiler water)	7	2610
Slate, black, soft	20	2630
Sand	115	2745
Sandy shale	155	2900
Shale, brown	140	3040
Shale, black brown, and bluish black	1263	4303

SOUTHERN OKLAHOMA DISTRICT.

Healdton Pool.

STELLA KECK, WELL No. 11, SEC. 5, T. 4 S., R. 3 W.

Formation	Thickness Feet	Depth Feet	Formation	Thickness Feet	Depth Feet
Blue soft shale	110	650	Blue shale	50	915
Light sand	50	700	Gray sandy shale	25	940
Light gas sand	20	720	Lime shell	10	950
Blue shale	65	785	Sandy lime	15	965
Gas sand	5	790	Oil sand	50	1015
Lime shell	20	810	Blue shale	18	1033
Oil sand	55	865			

W. DAVIS WELL No. 1, SEC. 6, T. 4 S., A. 3 W.

Formation	Thickness Feet	Depth Feet	Formation	Thickness Feet	Depth Feet
Surface	10	10	Lime shell	5	760
Red rock	115	125	Mud	10	770
Gas sand	20	145	Gas sand	8	778
Red rock	80	225	Mud	17	795
Gas sand	25	250	Gas sand	10	805
Red rock	50	300	Blue shale	60	865
Gas sand	75	375	Oil sand	5	870
Red rock	15	390	Blue shale	10	880
Oil sand	35	425	Oil sand	35	915
Blue shale	175	600	Shale	5	920
Gas sand	20	620	Lime shell	10	930
Blue shale	115	735	Blue shale	10	940
Lime shell	5	740	Oil sand	237	1177
Blue shale	15	755			

APPLE & FRANKLIN, WELL No. 1, SEC. 8, T. 4 S., R. 3 W.

Formation	Thickness Feet	Depth Feet	Formation	Thickness Feet	Depth Feet
Sand and gravel	3	18	Blue shale	20	360
Red rock	120	120	Sand	20	380
Water sand	30	150	Blue shale	246	626
Red rock	70	220	Gas sand (no gas)	8	634
Water sand	25	245	Blue shale	210	844
Red rock	35	280	Oil sand (2 bbl. well at 844)	41	885
Sand	25	305	Blue shale	46	931
Red rock	25	330	Oil sand (oil and gas at 933)	16	947
Water sand	10	340			

MOLLIE INGRAM, WELL No. 1, SEC. 17, T. 4 S., R. 3 W.

Formation	Thickness Feet	Depth Feet	Formation	Thickness Feet	Depth Feet
Soil	5	5	Sand and salt water	21	557
Red mud	65	70	Red shale	68	645
Blue mud	20	90	Sand and salt water	30	675
Red mud	55	145	Blue shale	20	695
Sand and water (s. w.)	15	160	Red shale	65	760
Red shale	10	170	White shale	15	775
Blue shale	20	190	Lime shell	5	780
Red shale	35	225	Sand and salt water	65	845
Sand and water (s. w.)	25	250	Blue shale	10	855
Red shale	24	274	Sand and salt water	10	865
Sand and water (s. w.)	26	300	Blue shale	5	870
Red shale	15	315	Sand and salt water	25	895
Sand and salt water	45	360	Brown shale	165	1000
Red shale	70	430	Sand and salt water	30	1030
Sand and water (s. w.)	45	475	Blue slate	20	1050
Red shale	81	556	Brown shale	50	1100

MOLLIE INGRAM WELL No. 1—(Continued)

Formation	Thickness Feet	Depth Feet	Formation	Thickness Feet	Depth Feet
Blue shale	35	1135	Blue shale	22	1322
Sand and salt water	20	1155	Sand and salt water	11	1333
Blue shale	5	1160	Sandy lime	8	1341
Red shale	20	1180	Dark blue shale	12	1353
Sand and salt water	25	1205	White shale	12	1365
Pink shale	35	1240	Brown shale	15	1380
Brown shale	20	1260	Sand and salt water	20	1400
Sand and salt water	12	1272	Blue shale	105	1505
Pink shale	8	1280	Sand and salt water	18	1523
Blue shale	10	1290	Blue shale	42	1565
Sand and salt water	10	1300	Sand and salt water	35	1600

R. V. NEWTON, WELL No. 1, SEC. 29, T. 4 S., R. 3 W.

Formation	Thickness Feet	Depth Feet	Formation	Thickness Feet	Depth Feet
Red clay	30	30	Red rock	22	710
Water sand	5	35	Water sand	20	730
Red rock	95	130	Red rock	70	800
Water sand	5	135	White shale	20	820
Red rock	235	370	Red rock	60	880
Gray slate	90	460	Brown shale	10	890
Water sand	5	465	Red rock	40	930
Red rock	45	510	White shale	20	950
Blue shale	120	630	Red rock	25	975
Water sand	5	35	Water sand	15	990
Blue sand-shale	45	680	Gray slate	13	1003
Water sand	8	688			

Local Pool.

LOG OF WELL, GALLOWAY No. 1, SEC. 6, T. 3 S., R. 5 W.

Formation	Thickness Feet	Depth Feet	Formation	Thickness Feet	Depth Feet
Shale	5	5	Blue shale	5	580
Blue shale	10	15	Red shale	15	595
White sand (some oil)	10	25	Blue shale	25	620
Brown shale	25	50	Salt and sand	45	665
Limestone	5	55	Blue shale	10	675
Blue shale	10	65	White sand (oil)	20	695
White sand	25	90	Blue shale	15	710
Limestone	8	98	Salt sand	50	760
White sand	12	110	Blue shale	50	810
Red shale	15	125	White sand	5	815
White sand (gas)	15	140	Lime	3	818
Blue shale	5	145	Blue shale	165	983
White sand	10	155	Water sand	2	985
Red shale	32	187	Blue shale	70	1055
White sand (some oil)	33	220	White lime	10	1065
Red shale	100	320	White sand (oil showing)	5	1070
Sand (some oil)	15	335	Blue shale	15	1085
Red shale	40	375	Gray lime	50	1135
Blue shale	10	385	Blue shale	15	1150
Sand (gas)	3	388	Gray lime	20	1170
Blue shale	7	395	Blue shale	15	1185
Sand (oil, 10 bbl.)	12	407	Gray lime	25	1210
Blue shale	5	412	White water sand	5	1215
Red shale	93	505	Gray lime	20	1235
Blue shale	5	510	Blue shale	2	1237
Sand (oil, 11 bbl.)	15	525	Gray lime	18	1255
Red shale	50	575	Blue lime	5	1260

The limestones from 1235 feet to the bot tom of the hole are impregnated with oil.

GOTEBO POOL.
LOG OF WELL SOUTH OF GOTEBO, KIOWA COUNTY.

Character of Formation	Thickness Feet	Depth Feet
Red and blue shale and sandstone	500	500
Thin limestone, shale and granite boulders	150	650
Hard blue limestone	80	730
Sandstone and shale, show of gas	20	750
Hard blue limestone	85	835
Red shale (caves badly)	15	850
Very hard limestone	270	1120
Brown slaty limestone	60	1180
White hard flinty limestone mud filled fissures	245	1425
Blue and black shale	200	1625
Grayish limestone	55	1680

Still in the limestone when the drilling was stopped.

BURKBURNETT POOL.
LOG OF TAYLOR WELL No. 1, NORTHEAST CORNER OF BLOCK 34, BURKBURNETT TOWNSITE.

Formation	Thickness Feet	Depth Feet
Surface, clay and sand	10	10
Red clay	12	22
Water sand	14	36
Red clay	7	43
Water sand	8	51
Shale	12	63
Red clay	25	88
Sand rock	15	103
Sand, hard	9	112
Shale	29	141
Sand rock	10	151
Shale	47	200
Sand rock	10	210
Shale	80	290
Sand rock	16	306
Shale	109	415
Oil sand	5	420
Shale, hard	15	435
Hard sand	10	445
Shale	131	576
Rock	4	580
Shale	20	600
Shale and boulders	15	615
Shale	10	625
Water sand	30	655
Shale	667	
Sand, hard	6	673
Shale	17	690
Rock	3	693
Shale	81	774
Sand rock	5	779
Shale	57	836
Gumbo	15	851
lime rock	2	853
Shale	65	918
Sand, hard	89	1007
Lime rock	3	1010
Sand, hard	50	1060
Shale	9	1069
Gumbo	74	1143
Lime rock	2	1145
Stickey shale	62	1207
Shale, hard	6	1213
Stickey shale	83	1296
Sand, hard	9	1305
Stickey shale	28	1333
Sand, hard	16	1349
Stickey sand	91	1440
Lime shell	4	1444
Stickey shale	38	1482
Lime shell	7	1489
Shale	11	1500
Gumbo	6	1506
Shale	46	1552
Lime	4	1556
Gumbo	15	1571
Sand	1	1572
Gumbo	31	1603
Sand	4	1607
Gumbo	36	1643
Sand, show of oil	4	1647
Gumbo	26	1663
Sand, show of oil	13	1676
Sandy lime	15	1681
Black shale	1	1682
Oil sand	15	1697
T. D.		1697

LOG OF MAXWELL WELL No. 1, 250 FT. E. AND 250 FT. S. OF NE. COR. BLOCK 104, JOHN DECK SURVEY.

Formation	Thickness Feet	Depth Feet
Surface	50	50
Sand	80	130
Pack sand	19	149
Mud	20	160
Sand rock	10	179
Gumbo	12	191
Sand	10	201
Mud	21	222
Sand	18	240
Mud	55	392

LOG OF MAXWELL WELL No. 1—(Continued)

Formation	Thickness Feet	Depth Feet
Blue Gumbo	10	402
Pack sand	20	422
Sand rock	2	424
Gumbo	20	444
Sand	3	447
Gumbo	11	458
Sand rock	10	468
Shale	70	538
Gumbo	26	564
Shale	18	582
Sand rock	10	592
Shale	18	610
Gumbo	4	614
Sand	6	620
Sand rock	8	628
Shale	12	640
Gumbo	19	659
Pack sand	3	662
Gumbo and sand	16	678
Sand rock	4	682
Shale	5	687
Sand rock	6	693
Shale	24	715
Sand rock	13	728
Shale	17	745
Gumbo	13	758
Shale	12	770
Sand rock	6	776
Gumbo	8	784
Sand	4	788
Shale	11	799
Gumbo	7	806
Shale	21	827
Gumbo	10	837
Shale	4	841
Gumbo	10	851
Shale	34	885
Sand rock	4	889
Shale	6	905
Gumbo	10	915
Shale	35	950
Sand rock	8	958
Lime	2	960
Rock	5	965
Gumbo	6	971
Sand and boulders	3	974
Sand rock	6	980
Shale	16	996
Sand rock	4	1000
Shale	12	1012
Sand rock	7	1019
Gumbo	8	1027
Sand rock	10	1037
Shale	8	1045
Sand	4	1049
Sand and lime	10	1059
Shale	10	1069
Sand rock	4	1073
Shale	12	1085
Sand rock	18	1103
Shale	19	1122
Gumbo	5	1127
Sand rock	10	1137
Shale	8	1135
Sand	2	1147
Gumbo	4	1151
Sand rock	6	1157
Shale	13	1170
Sand rock	8	1178
Sand	5	1183
Shale	8	1191
Gumbo	20	1211
Shale	8	1219
Gumbo	10	1229
Sand and rock	7	1236
Shale	7	1243
Broken sand	10	1253
Gumbo	10	1263
Shale	6	1269
Sand rock	8	1277
Gumbo	7	1284
Sand rock	7	1301
Shale	18	1319
Gumbo	22	1341
Sand	6	1347
Shale	10	1357
Gumbo	5	1362
Shale	8	1370
Sand rock	3	1373
Shale	5	1378
Gumbo	3	1381
Sand rock	9	1390
Shale	3	1402
Sandy lime	3	1405
Lime	2	1407
Sandy lime	2	1409
Sand rock	19	1429
Gumbo	10	1438
Shale	5	1443
Gumbo	10	1453
Shale	12	1465
Gumbo	11	1476
Shale	7	1482
Gumbo	13	1496
Shale	27	1523
Gumbo	10	1533
Shale	6	1539
Sand	6	1545
Shale	14	1559
Lime rock	1	1560
Lime	5	1565
Shale and broken lime	7	1572
Gumbo	5	1577
Shale and gumbo	18	1595
Gumbo	6	1601
Shale	12	1613
Lime rock	12	1615
Lime	1	1616
Shale	3	1619
Sand rock	9	1628
Shale	6	1634
Sand	6	1640
Gravel	5	1645
Sand and lime	2	1647
Shale	11	1658
Lime rock	3	1661
Shale	24	1685
Shale and gumbo	23	1708
Shale	7	1715
Lime rock	1	1716
Lime	3	1719
Gumbo	9	1728
Lime rock	2	1730
Lime	1	1731

LOG OF MAXWELL WELL No. 1—(Continued)

Formation	Thickness Feet	Depth Feet
Lime rock	4	1735
Shale	6	1741
Sand	18	1759
Gumbó	3	1762
Sand and lime	3	1765
Shale	14	1779
Lime and sand	6	1785
Shale	28	1813
Gumbo	6	1819
Shale	24	1843
Gumbo	4	1847
Shale	4	1851
Sandy lime	5	1856
Shale	2	1858
Sand	10	1868
Shale	20	1888
Sand and lime	3	1891
Sand rock and lime	8	1899
Gumbo	7	1906
Sand	10	1916
Sandy lime	8	1924
Sand	3	1927
Shale	19	1946
Sand rock	16	1962
Pack sand	23	1985
Shale	22	2007
T. D.		2007

LOG OF W. C. MYERS WELL No. 1., NE. COR. BLOCK 5, RED RIVER VALLEY LANDS.

Formation	Thickness Feet	Depth Feet
Surface	100	100
Shale	25	125
Sand	8	143
Shale	70	213
Sand	22	235
Shale	35	270
Sand	15	285
Red rock	45	330
Shale blue	20	350
Red rock	20	470
Red rock	100	570
Shale, blue	20	590
Dry sand	25	615
Red mud	40	655
Water sand	15	670
Red rock	10	680
Gray mud	25	705
Water sand	15	720
Red rock	40	760
Gray mud	10	770
Red mud	10	780
Water sand	25	805
Red mud	10	815
Gray mud	25	840
Sandy lime	3	843
Water sand	20	863
Red mud	20	883
Blue mud	5	888
Gray water sand	30	918
Blue mud	22	940
Water sand	40	980
Gumbo	20	1000
Red rock	40	1040
Shale	20	1060
Red rock	20	1080
Blue mud	20	1100
Blue mud	20	1120
Red mud	5	1125
Blue mud	15	1140
Red mud	20	1160
Blue mud	30	1190
Water sand	25	1215
Red rock	15	1230.
Red mud	30	1260
Red rock and blue shale	35	1295
Water sand	15	1310
blue shale	38	1348
Red rock	27	1375
Red mud	20	1395
Lime rock	12	1407
Blue shale	20	1427
Red rock	40	1467
Blue mud	33	1500
Blue shale	250	1750
Water sand	10	1765
Water sand	5	1770
Shale	20	1790
Blue shale	10	1800
Sandy shale and mud	18	1818
Water sand	27	1845
Broken lime	5	1850
Lime, hard	8	1858
Lime	32	1890
Lime shells and blue shale	40	1930
Gumbo	35	1965
Blue shale	70	2035
Gumbo	20	2055
Lime, hard	5	2060
Lime rock	1	2061
Lime	39	2200
Sand	10	2210
Pack sand	40	2250
Sand	30	2280
Hard white lime	20	2300

Dry and abandoned at 2300.

LOG OF GILLIS WELL No. 1, NE. COR. SOUTH 5 ACRES OF OUTER BLOCK No. 15, BURKBURNETT TOWNSITE.

Formation	Thickness Feet	Depth Feet
Clay	50	50
Sand	20	70
Clay	280	350
Sand	7	357
Clay	50	407
Sand	7	414
Gumbo	17	421
Sand	16	437
Clay	110	547
Lime	2	549
Clay	16	565
Sand	2	567
Clay	33	600
Gumbo	9	609
Gumbo	9	618
Clay	17	635
Sand	10	645
Clay	31	676
Gumbo	6	684
Sand	12	696
Clay	13	709
Gumbo	21	730
Sand	15	745
Gumbo	22	767
Clay	15	782
Sand	10	792
Clay	43	835
Sand	5	840
Gumbo	10	850
Clay	20	870
Gumbo	11	881
Clay	13	894
Gumbo	6	898
Clay	16	914
Gumbo	4	918
Clay	11	929
Sand	7	936
Clay	9	945
Clay	65	1010
Sand	25	1035
Sand	25	1060
Gumbo	6	1066
Clay	5	1071
Gumbo	4	1075
Clay	5	1080
Clay	10	1090
Sand	10	1100
Clay	75	1175
Sand	16	1191
Sand	25	1216
Gumbo	5	1221
Sand	10	1231
Clay	37	1268
Lime	2	1270
Clay	26	1296
Sandy lime	8	1304
Clay	8	1312
Gumbo	4	1316
Clay	29	1345
Gumbo	93	1438
Blue shale	5	1443
Sand	6	1449
Blue shale	15	1464
Gumbo	65	1529
Lime	2	1531
Gumbo	29	1560
Sand	6	1566
Hard sand	16	1582
Sand	3	1585
Shale	5	1590
Sand	5	1595
Gumbo	9	1614
Gumbo	3	1617
Shale	17	1634
Gumbo	9	1643
Sand	3	1646
Lime	1	1647
Lime	10	1657
Oil sand	26	1883

RANGER FIELD.

LOG OF McCLUSKY WELL No. 1, EASTLAND COUNTY, TEXAS.

Formation	Thickness Feet	Depth Feet
Lime	35	35
Yellow Clay	10	45
Blue shale	130	175
Limestone	40	215
Black shale	61	276
Sand, water	19	295
Light shale	59	354
Lime	15	369
Blue shale	11	380
Lime	15	392
Blue shale	65	460
Lime	38	498
Blue shale	22	320
Lime	20	340
Blue shale	30	370
Lime	10	380
Hard sand	10	390
Blue shale	380	770
Lime	30	800
Light hale	360	1160
Sandy shale, water	20	1180
Light shale	150	1330
Sand, salt water	60	1390
Light shale	325	1615
Lime	20	1635
Hard shale	25	1660
Sand	20	1680
Shale and lime	265	1945
Sand water	22	1967
Lime	23	1990
White shale	480	2470
Broken sand and shale	96	2566
Sand (show of oil)	6½	2572½
Sand and shells	156½	2740
Black shale	180	2920
Black lime	65	2985
Black shale	50	3035
Light shale	55	3090
Black shale	114	3204
Bottom	223	3427

Production 1500 Barrels.

LOG OF J. W. JONES WELL No. 1, F. CULLIMAN ET AL., HUMBLE OIL & GAS CO.

Formation	Thickness Feet	Depth Feet
Soil	10	10
Sand, dry	15	25
Red rock	5	30
Mixed gravel water	5	35
Blue mud	4	39
Gray lime	1	40
Blue clay	80	120
Gray lime	36	156
Blue shlae	24	170
Gray lime	2	172
Blue shale	83	235
Gray lime	4	239
Blue shale	15	254
Gray lime	31	285
Blue slate	115	400
Gray lime	2	402
Blue slate	30	432
Gray lime	8	440
Blue slate	16	456
Dry sand	12	468
Blue slate	17	485
Sandy lime	5	490
Blue slate	40	530
Gray lime	35	565
Blue slate	5	570
Red rock	10	580
Blue slate	47	627
Lime shell	4	631
White slate	14	645
Lime	9	654
Water sand	5	659
Blue shale	33	692
Lime	2	694
Sandy shale	34	728
Dry sand	18	746
Blue shale	69	815
Lime shell	6	821
Blue slate	17	838
Sandy lime	17	855
Blue shale	25	880
White lime	10	890
Brown shale	10	900
Blue shale	30	930
White lime	23	953
White slate	8	961
Brown slate	9	970
Lime shell	4	974
Broken water sand	21	995
Blue slate	35	1030
White lime	10	1040
Blue slate	35	1075
Lime shell	3	1078
Dry sand	20	1098
White slate	17	1115
White lime	122	1237
Dry sand	13	1250
Blue slate	75	1325
Lime shell	5	1330
Black shale	37	1367
Dry sand	16	1383
Hard lime	11	94
Dry sand	8	1402
Hard lime	31	1433
Blue shale	7	1440
Blue shale	10	1450
Blue shale	22	1472
Blue lime	8	1480
Light shale	23	1503
Lime	15	1518
Blue shale	157	1675
Hard brown lime	30	1705
Blue slate	35	1740
White lime	25	1765
Blue slate	83	1848
Gray lime	12	1860
Blue slate	15	1875
Blue lime	6	1881
Water sand	18	1899
Water sand	5	1904
Sandy lime	7	1911
Blue slate	4	1915
Water sand	18	1933
Blue slate	2	1935
White lime	12	1947
Blue slate	11	1958
Lime	7	1965
Blue slate	8	1973
Hard lime	5	1978
Blue slate	23	2001
Brown sandy shale	64	2065
Blue slate	336	2401
Sandy lime	8	2409
Blue shale	56	2465
Dry sand	26	2491
Blue slate	4	2495
Hard sand	7	2502
Blue slate	18	2520
Dry sand	6	2526
Blue slate	24	2550
Sandy shale	77	2627
Hard white lime	11	2638
Sandy shale	62	2700
Blue slate	60	2760
Black slate	90	2850
Black lime	7	2857
Blue slate	63	2920
Black slate and lime	27	2947
Black lime	26	2973
Blue slate	20	2993
Black slate	12	3005
Black lime	30	3035
Black slate	28	3063
Blue slate	4	3067
Black lime	4	3071
Brown shale	33	3104
Blue shale	31	3135
Black shale	5	3140
Black lime	4	3144
Gas sand (est. 3 million)	4	3148
Black sandy lime	12	3160
Black lime	39	3199
Brown shale	5	3204
Sandy broken lime	49	3253
Black slate cave	12	3265
Black lime	20	3285
Sand—show of gas	5	3290
Black lime (steel line)	19	3309
Sandy lime (show oil)	15	3324
Sandy shale	7	3331
Black shale	115	3446
Gray lime	18	3464
Black shale	7	3471
Lime shell	3	3474

Top of oil sand 3474.
Drilled in sand to 3492.

HUMBLE OIL & REFINING CO., SCHOOR No. 1, EASTLAND COUNTY, TEXAS, SEC. 50, H. T. C. R. R. SURVEY, BLOCK 3 ELEV. 1608'.

Formation	Thickness Feet	Depth Feet
Red soil	10	10
Blue lime	10	20
Red mud	25	45
Blue shale	45	90
Blue shale	30	120
Blue mud	10	130
Blue mud	50	180
Blue mud	20	200
White sand water	30	230
White sand	50	280
Blue gumbo	80	360
Red mud	20	380
White shale	20	400
Gray lime	25	425
Blue shale	15	440
Shale	20	460
Sand, white, water	5	3B-465
Coal	7	472
Sand, white	6	478
Shale, blue	22	500
Lime, white	10	510
Blue shale	70	580
Lime, gray	20	600
Blue shale	30	630
Gray lime	10	640
Blue shale	30	670
Gray lime	30	700
Gray lime	15	715
White shale	55	770
Sand, white, H. F. W.	30	800
Blue shale	50	850
Gray lime	60	910
White lime	15	925
Black shale	5	930
White lime	15	945
White sand	20	965
Broken lime	10	975
Blue shale	20	995
Blue shale	20	1015
Red mud	20	1035
Shale	17	1052
Black shale	23	1075
Slate	77	1235
Blue slate	45	1260
White lime	60	1340
Red mud	5	1345
Blue shale	85	1430
Blue shale	155	1585
White sand, water	5	1590
White sand, water	100	1690
Blue slate	60	1750
Brown shale	30	1780
Sand, H. F. W.	30	1810
Sand, hard	10	1820
Blue slate	5	1825
Black lime	10	1835
White sand, water	45	1880
Slate	20	1900
Lime	30	1930
Black slate	70	2000
White lime	10	2010
Black slate	90	2100
Brown slate	50	2150
Blue shale	10	2160
Lime	15	2175
Blue slate	25	2200
White lime	20	2220
Black slate	20	2240
Black slate	20	2260
Blue slate	20	2280
Blue slate	20	2300
Blue slate	100	2400
White lime	8	2408
White lime	4	2412
Black slate	8	2420
White lime	130	2550
Black slate	50	2600
Black slate, thin S.	50	2650
Black slate	85	2735
White shale	65	2800
Blue shale	10	2810
Blue shale	44	2854
Black lime	7	2861
Gray lime, 10% sand	5	2866
Gray lime, darker	5	2871
Gray lime, brown	4	2875
Black lime, hard	3	2878
Black lime, caving	1	2879
Black lime	2	2881
Black lime, shaley	3	2884
Black shale	3	2887
Black shale	5	2893
Black lime, hard	2	2895
Black lime, gray	5	2900
Black lime	2	2902
Black lime	2	2904
Black lime	2	2906
Black lime, hard	3	2909
Black lime	2	2911
Black lime	2	2913
Gray lime, hard	2	2915
Gray lime, hard	2	2917
Black lime, hard	3	2920
Black lime, gray	9	2929
Black lime, hard	1	2930
Dark gray lime, hard	2	2932
Black lime	5	2937
Dark gray lime	2	2939
Black lime, gray	2	2941
Gray lime	2	2943
Gray lime	4	2947
Gray lime, brown	2	2949
Lime, black	6	2955
Black shale	1	2956
Black lime	14	2970
Black lime	10	2980
Black lime	20	3000
Black lime	20	3020
Black lime	30	3050
Black slate	10	3060
Black lime	15	3075
Black lime	5	3080
Black shale	20	3100
Black shale	15	3115
Black lime	13	3128
Showing of oil and gas		3122-26

LOG OF TEXAS & PACIFIC COAL & OIL CO., L. SHOOK No. 1, (J. W. SHOOK); WM. FRELLS SURVEY, EASTLAND COUNTY, TEXAS.

Formation	Thickness Feet	Depth Feet	Formation	Thickness Feet	Depth Feet
Drift	10	10	Blue slate	155	1095
Yellow mud	15	25	Black lime	45	1140
Blue slate and shells	45	70	Gray shale	60	1200
Sandy shale	20	160	Black shale	340	1540
Sandy shale	20	180	Black lime	30	1570
Slate	30	210	Black shale	10	1580
Water sand	20	230	Lime	40	1620
Slate and shells	5	295	Shale	20	1640
Lime	30	325	Sand	30	1670
Sandy shale	15	340	Shale	50	1720
Lime	10	350	Lime	10	1730
Blue slate	45	395	Shale	50	1780
Lime	20	415	Sand	32	1812
Black slate	5	420	Broken lime	38	1850
Lime	10	430	Blue slate	475	2325
Pink shale	20	450	Sand	25	2350
Slate and shells	50	500	Brown shale	531	2881
Sharp sand and water	30	530	Lime and shale	193	3074
Lime	5	535	Dark lime	52	3126
Sand and water	15	550	Brown shale	50	3176
Black shale	10	560	Black lime	4	3180
Sand and water	20	580	Gas sand	15	3195
Blue slate	80	640	Black lime	55	3250
Sand and shale	14	654	Broken lime	2	3252
Blue slate	56	710	Gray lime	8	3360
Lime	5	715	Gas and oil sand	45	3405
Black slate	120	835	Broken sand	13	3418
Sand showing oil	15	850	Black shale	15	3433
Blue slate	90	940	Total depth.		

DUKE POOL.

LOG OF WELL, KNOWLES No. 1, COMANCHE COUNTY.

Formation	Thickness Feet	Depth Feet	Formation	Thickness Feet	Depth Feet
Clay	0	20	Sand	15	720
Conglomerate	20	40	Brown slate	80	800
White mud	10	50	White slate	50	850
Gravel	5	55	Brown slate	50	900
Lime	10	65	Lime	10	910
White slate	28	93	White slate	30	940
Sand	17	110	Lime	10	950
Brown slate	50	160	White slate	20	970
White slate	25	185	Sand	10	980
Lime	15	200	Brown slate	70	1050
Sand	25	225	Sand, hole full of water	10	1060
Brown slate	50	275	Sand	20	1080
Sand	25	300	White slate	20	1100
Black slate	50	350	Brown slate	75	1175
Sand	40	390	White slate	25	1200
White slate	5	395	Black slate	20	1220
White sand	45	440	Shells	10	1230
White sand	5	445	White slate	70	1300
Sand	80	525	Black slate	40	1340
Slate	25	550	Brown slate	60	1400
Hard lime shells	20	570	White slate	50	1450
Slate	10	580	Shelly lime	50	1500
Lime	20	600	White slate	40	1540
Slate	5	605	White sand	50	1650
Lime	10	615	Gray lime	30	1680
Slate	30	645	Sand	50	1720
Lime	10	655	White slate	10	1730
Slate	50	705			

LOG OF WELL KNOWLES No. 1—(Continued)

Formation	Thickness Feet	Depth Feet
Sandy lime	30	1760
Sand (salt water)	110	18.0
Brown shale	25	1895
Lime	5	1900
Sandy lime	40	1940
Brown slate	10	1950
Sandy lime	60	2010
Black shale	20	2030
Sand	20	2050
Lime	30	2080
Black slate	20	2100
Sandy lime	20	2120
Brown shale	20	2140
Sandy lime	30	2170
Sand	40	2210
Black slate	5	2215
Brown slate	15	2430
Brown shale	30	2460
Black slate	100	2560
Lime	10	2670
Lime		2690

REFINERIES

The following lists give the locations, capacities and operating companies of the refineries in Kansas, Oklahoma, Texas and Louisiana together with the source and gravity of the crudes which are refined.

KANSAS REFINERIES OPERATING ON CRUDE FROM INDIVIDUAL FIELDS (Aug, 1918)

NAME AND LOCATION OF COMPANY	YEAR BUILT	PRESENT CAPACITY	SOURCE OF CRUDE	GRAVITY
Augusta Refining Company, Augusta	1917	5000	Augusta	32-36
Bliss Oil & Refining Company, Augusta	1916	1500	Augusta	32-36
Commonwealth Refining Company, Moran	1905	500	Moran	24-26
El Dorado Refining Company, El Dorado	1916	2000	Eldorado	34-36
Evans-Thwig Company, Wichita	1917	3500	Eldorado	34-36
Evans-Thwig Company, Kansas City	1917	3500	Eldorado	34-36
Golden Rule Refining Company, Wichita	1917	500	Potwin	42-
Great Western Refining Company, Erie	1905	700	Shut down	
Hutchinson Refining Company, Hutchinson	1915	1500	Eldorado	34-36
Kanotex Refining Company, Arkansas City	1917	800	Blackwell	39-
Kansas Co-Operative Company, Chanute	1906	800	Eldorado	34-36
Lesh Refining Company, Arkansas City	1914	1200	Blackwell	39-
Midland Refining Company, El Dorado	1917	4000	Eldorado	34-36
Kansas Oil & Refining Company, Coffeyville	1906	1500	Alluwee	30-32
North American Refining Company, Rosedale	1915	1000	Cushing	40-
White Eagle Refining Company, Augusta	1916	5000	Augusta	35½
Wichita Independent Refining Company, Wichita	1916	2500	Eldorado	34-
Western Refining Company, Wichita	1916	2000	Eldorado	34-
O. K. Refining Company, Niotaze	1905	1200	Okmulgee	35-38
Trapshooters Refining Company, El Dorado	1917	1000	Eldorado	34-36
St. Louis Refining Company, El Dorado	1917	700	Eldorado	34-36

KANSAS REFINERIES OPERATING ON CRUDE FROM VARIOUS FIELDS.

NAME AND LOCATION OF COMPANY	YEAR BUILT	PRESENT CAPACITY	SOURCE OF CRUDE
Empire Refinery, Independence	1909	2500	Wayside, Nowata, Kansas, Healdton
Milliken Refg. Co., Arkansas City	1917	6000	Blackwell and Butler County
National Refg. Co., Coffeyville	1907	5000	Nowata, Bartlesville and Kansas
Sinclair O. & R. Co., Kansas City	1917	4000	Kansas and Oklahoma
Sinclair O. & R. Co., Coffeyville	1909	6000	Kansas and Oklahoma
Standard Oil of Kansas, Neodosha	1892	25000	Kansas and Oklahoma
Uncle Sam Oil Co., Cherryvale	1906	600	Shut down
Wright Producing Co., Cherryvale	1917	1000	Kansas and Oklahoma
Sinclair Refg. Co., Chanute	1907	2000	Shut down
Miller Refg. Co., Chanute	1906	500	Various Oklahoma Fields
Kansas City Refg. Co., Kansas City, Ks.	1906	1650	Eldorado and Eureka

OKLAHOMA REFINERIES OPERATING ON CRUDE FROM INDIVIDUAL FIELDS (Aug. 15, 1918)

NAME AND LOCATION OF COMPANY	YEAR BUILT	PRESENT CAPACITY	SOURCE OF CRUDE	GRAVITY
Acme Refining Co., Jennings	1917	1500	Jennings	34-36
Ardmore Refining Co., (Ohio Cities), Ardmore	1915	6000	Healdton	31
Bigheart Refg. & Pet. Co., Bigheart	1900	800	Osage	32-35
Boynton Refg. Co., Boynton	1914	2500	Boynton	35-38
Carter Oil Co., Norfolk	1916	40000	Shut down	
American Oil & Tank Line Co., Cleveland	1913	600	Cleveland	32-35

NAME AND LOCATION OF COMPANY	YEAR BUILT	PRESENT CAPACITY	SOURCE OF CRUDE	GRAVITY
Consumers Refg. Co., Cushing	1915	5000	Cushing	40
Continental Refg. Co., Bristow	1914	2500	Cushing	40
Champion Refg. Co., Enid	1917	1000	Garber	43–47
Crescent Refg. Co., Newkirk	1917	3000	Mervine and Blackwell	39
Crystal White Refg. Co., Allen	1915	800	Allen	32
Occident Oil & Refg. Co., Cushing	1917	600	Quay	34–36
Duluth Refg. Co., Sapulpa	1917	2000	Sapulpa	34–38
Empire Refineries, Ponca City	1912	2500	Kansas	34–36
Empire Refineries, Oklahoma City	1906	1500	Billings	42
Equality Refining Co., Oilton	1917	600	Shut down	
Great American Refg. Co., Jennings	1917	1500	Quay	34–36
Hillman Refg. Co., Cushing	1914	700	Quay	34–36
Home Oil & Refg. Co., Yale	1917	2000	Quay	34–36
Illinois Refg. Co., Cushing	1914	1500	Quay	34–36
Imperial Refg. Co., Ardmore	1917	1000	Healdton	31
Inland Refining Co., Cushing	1911	4000	Cushing	40
International (Ohio Cities), Cushing	1915	5000	Cushing	40
Interstate Refg. Co., Drumright	1917	1000	Quay	34–36
Canfield Refg. Co., Yale	1916	600	Quay	34–36
Lake Park Refg. Co., Ponca City	1917	1000	Blackwell	39
Mid-Co. Gasoline Co., West Tulsa	1916	2000	Billings	42
Muskogee Refg. Co., Muskogee	1905	500	Muskogee	34–39
New England Refg. Co., Oilton	1913	1500	Cushing	40
North American Refg. Co., Pemeta	1915	2200	Cushing	40
Nyanza Pet. Co., Wilson	1917	1600	Healdton	31
Oilton Refg. Co., Oilton	1917	700	Shut down	
Producers & Refg. Corp., Blackwell	1916	2500	Blackwell	39
Phoenix Refg. Co., Sand Springs	1913	3500	Cushing	40
Process Refining Co., Cushing	1917	600	Cushing	40
Sinclair Refg. Co., Muskogee	1905	600	Muskogee	34–39
Stewart Refg. Co., Tulsa	1906	1500		
Sun Oil Co., Yale	1915	2500	Quay	34–36
Okmulgee Prod. & Refg. Co., Okmulgee	1916	1000	Okmulgee	35-38
Wabash Refg. Co., Hominy	1917	800	Shut down	
Yale Oil & Refg. Co., Yale	1916	1000	Quay	34-36
Pawnee Bill Refg. Co., Yale	1917	2000	Quay	34-36
Superior Refining Co., Covington	1917	1000	Garber	43-47
New Wilson Refg. Co., Wilson	1917	1000	Healdton	31
Globe Refg. Co., Blackwell	1917	1500	Blackwell	39
Chickasha Refg. Co., Ardmore	1917	1000	Healdton	31
Victor Refg. Co., Oilton	1917	1000	Quay	34-36
National Refg. Co., Cushing	1916	1200	Garber	43-47
Oilton Refg. Co., Oilton	1916	500	Shut down	
Cameron Refg. Co., Healdton	1917	1000	Healdton	31
Chickasha Refg. Co., Ardmore	1917	1000	Healdton	31

OKLAHOMA REFINERIES RUNNING ON CRUDE FROM VARIOUS FIELDS

NAME AND LOCATION OF COMPANY	YEAR BUILT	PRESENT CAPACITY	SOURCE OF CRUDE	
Constantine Refg. Co., Tulsa	1911	10000	Cushing, Okmulgee, Boynton	
Cosden & Co., Tulsa	1912	30000	Okmulgee, Glenn Pool, Cushing, Kansas	
Empire Refineries, Okmulgee	1907	2000	Okmulgee and Kansas	
Empire Refineries (2 plants) Cushing	1912	4000	Billings and Kansas	
Pierce Oil Corp., Sand Springs	1913	10000	Kansas, Cushing, Okmulgee, Glenn Pool	
Roxanna Pet. Co., Cushing	1916	10000	Healdton and Cushing	
Sapulpa Refg. Co., Sapulpa	1908	7000	Okmulgee, Sapulpa and Cushing	
Sinclair Refg. Co., Vinita	1910	10000	Garber and Cushing	
Sinclair Refg. Co., Cushing	1914	6500	Cushing and Osage	
Southern Oil Corp., Yale	1915	5000	Cushing, Osage and Quay	
Texas Co., Tulsa	1910	10000	Various Oklahoma fields	
Lawton Refg. Co., Lawton	1916	500	Healdton, Garber, Gotebo	23-49
Lake Park Refg. Co., Okmulgee	1915	800	Cushing and Okmulgee	
Marl and Refg., Ponca	1917	2000	Ponca and Mervine, Avg. Gr. 39	
Pan-American Refg. Co., Tulsa	1916	2000	Okmulgee, Cushing, Kansas	
Allied Refg. Co., Okmulgee	1917	1500	Okmulgee and Billings	
Indiahoma Refg. Co., Okmulgee	1910	3500	Okmulgee, Cushing, Kansas	

TEXAS REFINERIES OPERATING ON CRUDE FROM INDIVIDUAL FIELDS (July, 1918)

NAME AND LOCATION OF COMPANY	YEAR BUILT	PRESENT CAPACITY	SOURCE OF CRUDE	GRAVITY
Wichita Valley Refg. Co., Iowa Park	1914	1000	Electra	40
Panhandle Refg. Co., Wichita Falls	1915	2500	Burkburnett	39-40
Petroleum Refg. Co., Galena	1916	15000	Humble	23-26
Texas Co., Port Neches	1906	10000	Mexican	12-21
Thrall Oil Refg., Thrall	1915	1000	Thrall	
Carson Refg. Co., Brownwood	1918	400	Brownwood	36
Brownwood Refg. Co., Brownwood	1918	500	Brownwood	36
Golebo Refg. Co., Brownwood	1918	400	Brownwood	36
Oriental Refg. Co., Dallas	1912	1800	North Texas	39

This is an asphalt plant. Toppings of crude are piped to Port Arthur Refinery.

TEXAS REFINERIES OPERATING ON CRUDE FROM VARIOUS FIELDS

NAME AND LOCATION OF COMPANY	YEAR BUILT	PRESENT CAPACITY	SOURCE OF CRUDE
Avis Refining Co., Near Jacksboro	1915	300	Wherever they can obtain crude
Empire Refineries, Gainesville	1915	9000	Healdton and Brownwood
Gulf Refining Co., Port Arthur	1901	50000	Various Gulf Coast, Okla. & Kans. Fields
Gulf Refining Co., Ft. Worth	1911	6000	Kansas and Oklahoma
Magnolia Pet. Co., Ft. Worth	1914	12000	Healdton, Cushing and North Texas
Magnolia Pet. Co., Corsicana	1898	3000	Texas and Oklahoma
Magnolia Pet. Co., Beaumont	1902	25000	Texas, Oklahoma and Louisiana
Pierce Fordyce, Texas City	1911	3000	Texas and Mexico
Pierce Fordyce, Ft. Worth	1912	6000	Texas and Oklahoma
Texas Co., Port Arthur	1902	25000	Texas, Oklahoma and Louisiana
Texas Co., Dallas	1908	15000	Texas and Oklahoma
Seaboard Oil & Refg. Co., Orange	----	2500	Texas and Louisiana
Hoffman Oil & Refg. Co., Houston	1917	1200	Humble and Goose Creek
Humble Oil & Refg. Co., San Antonio	1913	1800	San Antonio and North Texas
Humble Oil & Refg. Co., Humble	----	500	North Texas and Humble

The following list includes the refineries listed above, together with those recently finished and those under construction.

The state of Texas has forty-three refineries including nine that are in course of construction. Those in operation have a combined capacity of about 263,000 barrels of crude and the nine being constructed have a total capacity of 14,200 barrels.

The following is a list of the refineries in Texas, showing the year built and the capacity of each March 1, 1919.

YEAR BUILT	COMPANY	LOCATION	CAPACITY
1902	The Texas Co.	Port Arthur	45,000
1906	The Texas Co.	Port Neches	10,000
1908	The Texas Co.	Dallas	15,000
1902	Magnolia Pet. Co.	Beaumont	55,000
1914	Magnolia Pet. Co.	Fort Worth	15,000
1898	Magnolia Pet. Co.	Corsicana	3,000
1901	Gulf Refg. Co.	Port Arthur	55,000
1911	Gulf Refg. Co.	Fort Worth	5,000
1911	Pierce Oil Corp.	Texas City	5,000
1912	Pierce Oil Corp.	Fort Worth	15,000
1913	Humble Oil & Refg.	San Antonio	1,800
1916	Humble Oil & Refg.	Humble	600
1917	Pet. Ref. Co. of Texas	Houston	1,000
1918	Sinclair Gulf Oil Corp.	Houston	6,000
1917	Hoffman Oil & Refg.	Houston	1,000
1918	Trans-Atlantic Pet.	Houston	1,200
1916	Mary Owens Oil Co.	Humble	300
1916	Slimp Oil Co.	Somerset	300
1917	Seaboard Oil & Refg.	Orange	2,000
1916	Black Diamond Oil	Thrall	300
1917	Robert Lignon	El Paso	200

1903	Central Oil Co.	Corsicana	300
1915	Producers Ref. Co.	Gainesville	15,000
1915	Panhandle Ref.	Wichita Falls	4,500
1914	Wichita Valley Refg.	Iowa Park	1,200
1915	Avis Refg. Co.	Jacksboro	300
1912	Oriental Refg. Co.	Dallas	1,800
1918	Hercules Oil & Ref. Co.	Dallas	1,200
1916	Eureka Refg. (tar)	La Porte	100
1918	Burkburnett Refg.	Burkburnett	1,000
1918	Odessa Oil & Refg.	Ranger	3,600
1918	Carson Oil & Refg.	Brownwood	300
1918	Brownwood Oil & Refg.	Brownwood	600
1903	United Oil & Refg.	Beaumont	2,000
Bldg.	Great Southern Oil & Refg.	Eastland	1,200
Bldg.	Eastland Oil & Refg.	Eastland	600
Bldg.	Lone Star Oil & Refg.	Coleman	500
Bldg.	Sunshine State Oil & Refg.	Electra	1,200
Bldg.	Southern Oil & Refg. Assn.	Fort Worth	500
Bldg.	Beaver Valley Oil & Refg.	Cisco	1,000
Bldg.	Liberty Refg. Co.	Cisco	600
Bldg.	Gilliland & Fisher	Wichita Falls	1,200
Bldg.	Eggleston & Todd	San Antonio	1,200

LOUISIANA REFINERIES OPERATING ON CRUDE FROM INDIVIDUAL FIELDS, JULY 1, 1918

Name of Company	Location	Year Built	Present Capacity	Source of Crude	Gravity
American Oil Refg. Co.	Cedar Grove		175	Caddo	18-28
Marine Oil & Refg. Co.	Cedar Grove		1200	Caddo	18-28
Caddo Oil & Refg. Co.	Shreveport	1917	1700	Caddo	18-28
Shreveport Oil & Refg. Co.	Shreveport	1911	1300	Caddo	18-28

LOUISIANA REFINERIES OPERATING ON VARIOUS CRUDES.

Name of Company	Location	Year Built	Present Capacity	Source of Crude
Liberty Oil & Refg. Co.	New Orleans	1915	500	Various Okla. Crudes
Pelican Oil & Refg. Co.	Chalmotte	1915	500	Mooringsport & Lenzberg
Standard Oil Co.	Baton Rouge	1910	20000	Texas and Oklahoma
Louisiana Refg. Co.	Gas Center	1913	3000	Various Louisiana Crudes
Mexican Pet. Corp.	Destrahan		6000	Topping Mexican Crude
Freeport & Mex. Fuel Corp.	Mereaux			Topping Mexican Crude
Roxanna Pet. Co.	New Orleans	1916	10000	Various Crudes

PIPE LINES

The states included in the Mid-Continent fields are well supplied with pipe line facilities. Besides the smaller lines supplying local refineries, there are trunk lines which carry the oil to the large refineries on the Gulf Coast, on Lake Michigan, and on the Atlantic sea-board.

In the following pages a very brief statement of the pipe lines of Kansas, Oklahoma and Texas, is given. The data are compiled from the Interstate Commerce Commission map for Kansas, the State Corporation Commission map for Oklahoma and a pamphlet issued by the Chamber of Commerce of Fort Worth for Texas.

KANSAS.

The principal trunk pipe-lines of Kansas are those of the Prairie Pipe Line Company and of the Sinclair interests, which enter the State near Coffeyville and Caney, and extend northeastward past Kansas City.

The Prairie Pipe Line Company has many branch lines, including one to El Dorado and Augusta, and besides these, there are many smaller collecting and refinery lines in the eastern part of the State. The El Dorado and Augusta fields are tapped by their main lines from the south and also has smaller refinery lines.

OKLAHOMA.

The pipe-lines in Oklahoma are confined to the eastern part of the State, clustering thickly in the Glenn Pool, Cushing Pool and Washington and Osage County districts and radiating to the south, southeast and northeast, and connecting with the Healdton Pool to the southwest.

The greatest pipe-line mileage of any one company in Oklahoma is that of the Prairie Pipe Line Company (Standard oil interests) which was the first company in the field and which, for several years, controlled the transportation and marketing conditions in the State. This company has a number of 6-inch and 8-inch lines from the Glenn Pool and Cushing Pool, which unite near Ramona and continue northward to the Kansas line and eventually to the refineries at Whiting, Indiana, and Bayonne, New Jersey.

Another feeder to the main lines is an 8-inch line from the Blackwell field to Caney, Kansas. The total mileage of the company in Oklahoma, exclusive of gathering lines, is about 400 miles.

The mileage of the Texas Pipe Line Company is practically the same as that of the Prairie. The main line of this company is an 8-inch line which extends nearly south from the Glenn pool to Red river, south of Durant. There are important feeders from the Cushing pool, from the pools to the north of Tulsa and from the Okmulgee county pools. An 8-inch line taps the Healdton pool and extends southeastward joining the main line at Sherman, Texas. The lines of this system carry the oil south, supplying the Texas company's refinery at Port Arthur, Texas. The total mileage of the company in Oklahoma is about 375 miles.

The Magnolia Pipe Line Company has an 8-inch line from the Cushing district southwest to Red river, south of Waurika and one 8-inch and two 6-inch lines from the Healdton field. These lines connect with the main trunk line of the company in the Petrolia district and carry the oil eventually to the Magnolia refinery at Beaumont, Texas, and to the coast at Sabine. The trunk lines in Oklahoma have a length of about 350 miles.

The Oklahoma Pipe Line Company has a double trunk line from the Glenn pool district to McCurtain station near the southeastern corner of the State, with feeders from the El Dorado and Augusta, Kansas fields, the Cushing district and various pools in Okmulgee and Muskogee counties. The total mileage is slightly above 300 miles. The terminal of the line is at Baton Rouge, La.

The Gulf Pipe Line Company and the Gulf Pipe Line Company of Oklahoma, have together slightly less than 300 miles of trunk line in Oklahoma. The main line extends nearly south from the Glenn pool region crossing Red river south of Hugo. This line has feeders from El Dorado and Augusta, Cushing and the Bartlesville district. The terminus of the line is at Port Arthur, Texas.

The Yarhola Pipe Line Company (Dutch-Shell interests) has a 6-inch line form Healdton to the Cushing field, and a 10-inch line from Cushing to the northeast, reaching St. Louis. The total length is over 250 miles.

The Empire Pipe Line Company has a line from the El Dorado and Augusta fields to Guthrie and from Guthrie east to Cushing, and another line running east from Ponca City and then south to Cushing. Another line of this company extends from the Healdton field to a refinery at Gainesville, Texas, and a line from Burkburnett, Texas, to Healdton, is under construction. The total length of the lines already built is about 150 miles.

The exact lengths of the trunk lines mentioned above is given as follows: (July, 1918).

Prairie Pipe Line Company	378.26
Texas Pipe Line Company	377.79
Magnolia Pipe Line Company	340.56
Oklahoma Pipe Line Company	310.18
Yarhola Pipe Line Company	266.75
Empire Pipe Line Company	154.27
Gulf Pipe Line Company	180.14
Gulf Pipe Line Company of Oklahoma	116.25
Total	2,124.22

Besides the lines reported above, the Sinclair interests have a considerable mileage in Oklahoma and there are several smaller transporting and refinery lines besides the still smaller gathering lines in the fields and from the fields to the railroads.

TEXAS.

The combined mileage of all Texas trunk pipe lines utilized for the transportation of petroleum is approximately 3,116 miles, according to data compiled by the Research and Publicity Bureau of the Fort Worth Chamber of Commerce. These figures include all completed lines as well as those upon which actual construction is now under way, or in actual contemplation.

The replacement value of the pipe line systems of Texas, according to the best estimates available, is $80,000,000, which is more than the value of the present annual Texas petroleum output. The field storage capacity from which the Texas pipe lines systems are supplied is approximately 15,000,000 barrels, and is sufficient to accommodate 50 per cent of the last year's oil production of the State.

The State's pipe lines tap 25,000,000 acres of mapped oil lands and transport the production from over 8,000 Texas wells, with an annual output of nearly 30,000,000 barrels. They also connect with a network of lines reaching into Oklahoma, Kansas and Louisiana, through which approximately 40,000,000 barrels additional crude petroleum are transported each year. Nearly one-third of the total output of the United States passes through Texas pipe lines.

The pipe line mileage operated by each company and the size of the various Texas lines is as follows:

Name	Miles 6-in.	Miles 8-in.	Miles 12-in.	Miles Total
Gulf Company	285	391	----	676
Magnolia Company	----	876	----	876
Texas Company	145	725	----	870
Sun Company	82	64	----	146
Empire Company	----	17	----	17
Pierce Company	----	76	----	76
Prairie Company	----	130	325	455
TOTAL	512	2279	325	3116

It will be observed that the Magnolia, Texas and Gulf companies are the leading pipe line concerns operating in Texas, controlling over 80 per cent of the total mileage.

The longest continuous pipe line in the State is the 400-mile Texas company line between Port Arthur and Denison.

In addition to the trunk pipe lines there is a vast amount of smaller field lines usually known as gathering systems which are not included in the total main line mileage. Practically all companies operate more or less of these gathering lines.

The Magnolia Petroleum Company's line between the Red river and its Beaumont refinery consists of a double 8-inch line, and while this company's system of pipes are supplied mainly from the Wichita county and Oklahoma fields, it operates a greater mileage than any other company in the State.

Gulf Pipe Line Company—			
Fort Worth to Saltillo	6-inch	124 miles	
Houston to Sour Lake	6-inch	68 miles	
Caddo to Lufkin	6-inch	98 miles	
Olean to Red River	8-inch	305 miles	
Ranger to Fort Worth	8-inch	86 miles	
TOTAL			676 miles
Magnolia Petroleum Company—			
Double 8-inch line, Red River to Beaumont		800 miles	
Single 8-inch line, Electra to Bowie		76 miles	
TOTAL			876 miles
The Texas Company—			
Denison to Port Arthur	8-inch	400 miles	
Logansport to Port Arthur	8-inch	155 miles	
Ranger to Fort Worth	8-inch	85 miles	
Dallas to Fort Worth	8-inch	30 miles	
Dallas to Fort Worth	8-inch	30 miles	
Dayton to Goose Creek	8-inch	25 miles	
Electra to Fort Worth	6-inch	130 miles	
Humble to Houston	6-inch	15 miles	
TOTAL			870 miles
Sun Pipe Line Company—			
Humble to Sour Lake	6-inch	53 miles	
Batson to Sour Lake	8-inch	16 miles	
Sour Lake to Spindle Top	8-inch	23 miles	
Spindle Top to Sabine Pass	6-inch	25 miles	
Spindle Top to Sabine Pass	8-inch	25 miles	
Spindle Top to Sun Station	6-inch	4 miles	
TOTAL			146 miles
Prairie Pipe Line Company—			
*Ranger to Galveston	12-inch	325 miles	
Ranger to Red River	8-inch	130 miles	
TOTAL			455 miles
Pierce Pipe Line Company—			
Fort Worth to Red River	8-inch		76 miles
Empire Pipe Line Company—			
Gainesville to Red River	8-inch		17 miles
GRAND TOTAL			3,116 miles

*Construction temporarily postponed.

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